Detector Requirements from Physics at Future e^+e^- EWK/Higgs/Top factories

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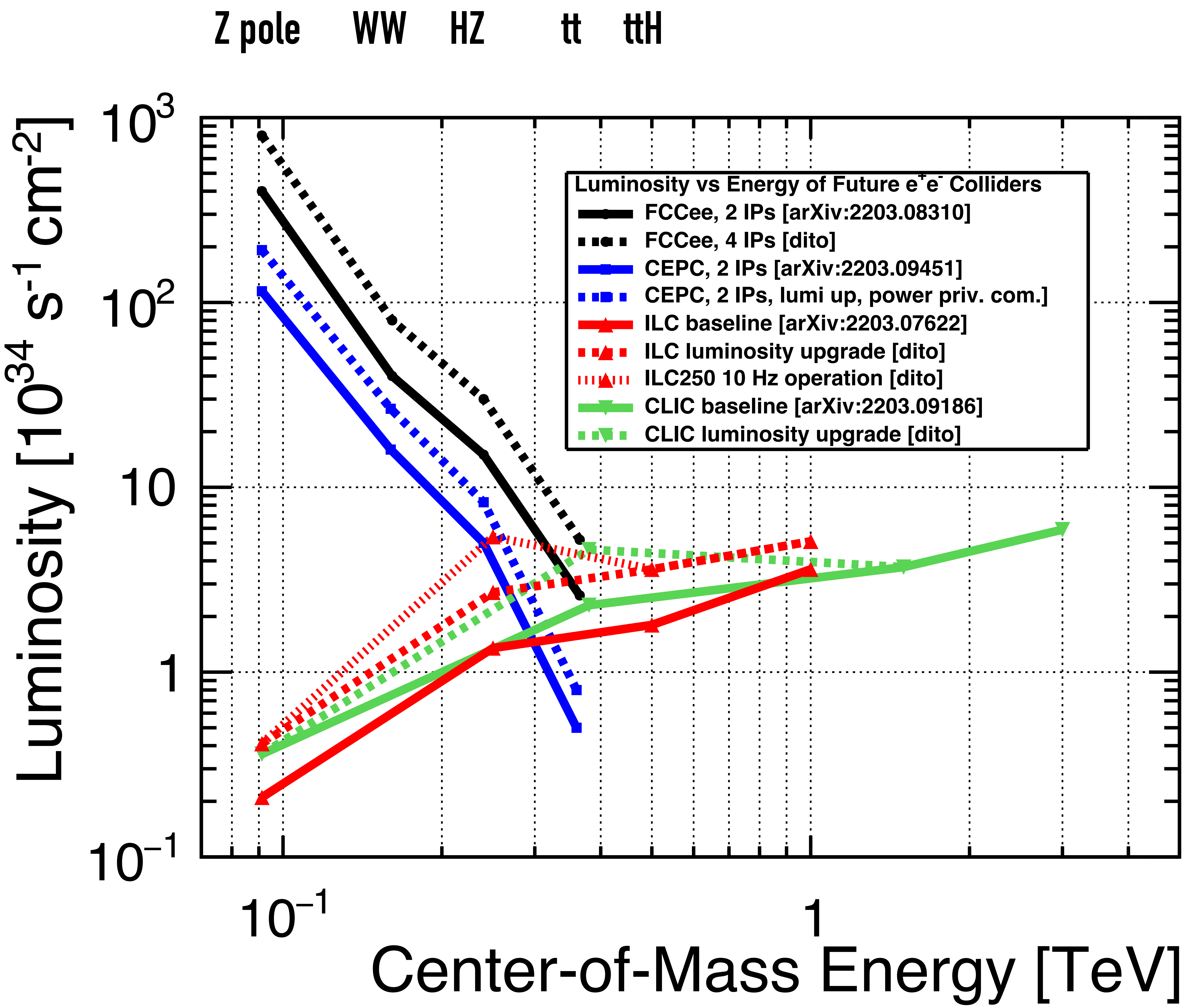
Future Collider Seminar Series
CERN June 20, 2023

This is a quick summary of a huge amount of work by many.

FUTURE e^+e^- COLLIDERS



Can produce all the heaviest particles of the Standard Model

- CC can obtain very high luminosity, especially at lower energies.
  - Bremstrahlung limits the energy reach.
- LC able to reach high energies.
  - Advantages of using longitudinally polarised beams.

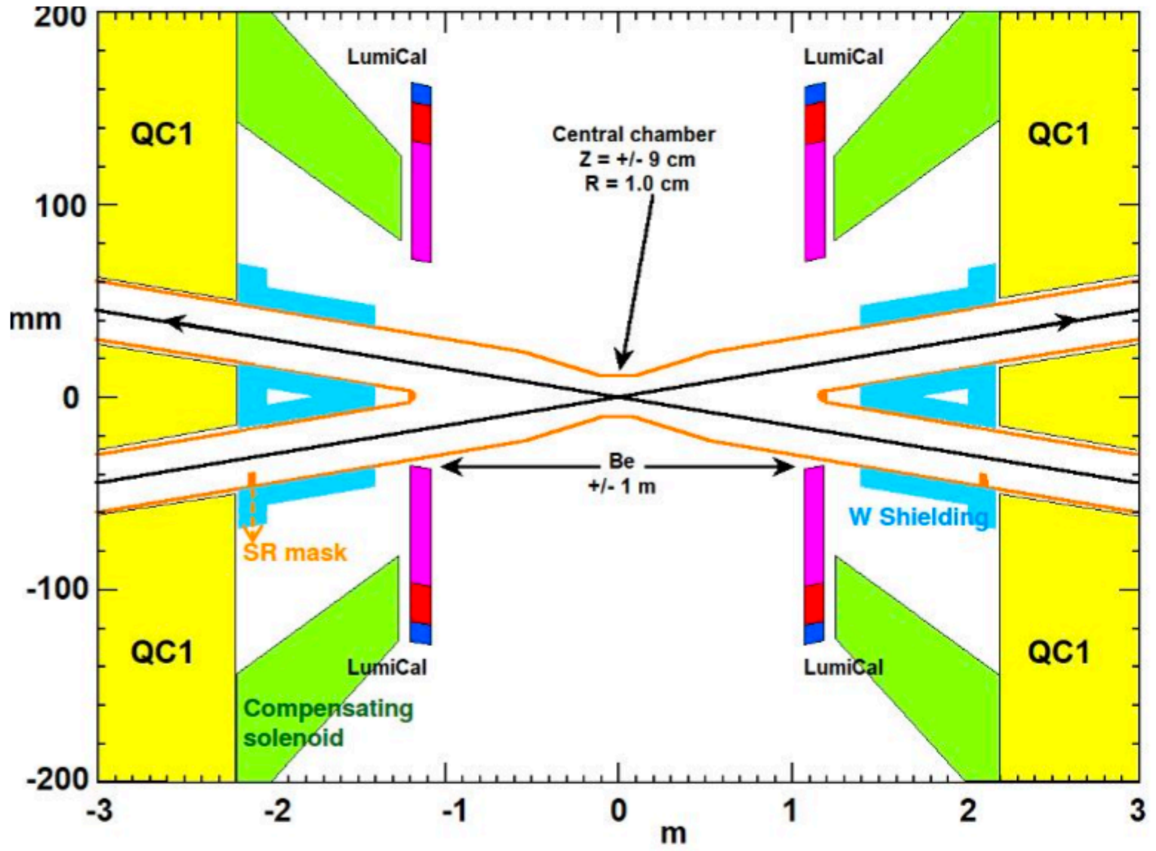
[from Snowmass document]

More in the next talk!

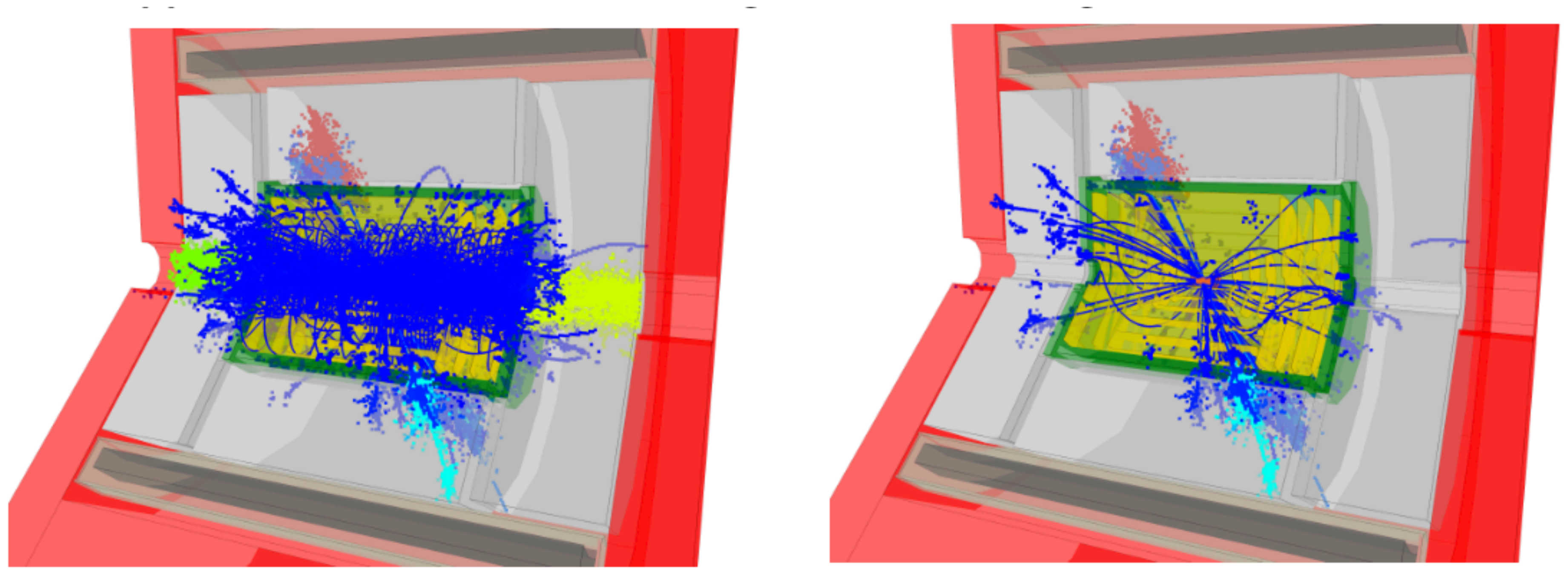
REQUIREMENTS FROM MACHINE

- Requirement from Physics are not limited to the detectors characteristics but also to the environmental conditions imposed by the machine and the energy range considered.
- Contrary to hadron machines, e^+e^- collisions provide a precisely known center or mass energy, polarisation and luminosity, lower background, trigger less operations. In addition:
    - **Linear:** beam time structure allows for a 1% duty cycle, passive cooling allows lower material budget, can reach high energies but suffer from beamstrahlung background (constrains beam pipe radius and vertex location)
    - **Circular:** less affected by beamstrahlung, higher luminosity (especially at lower √s), and very high collision rate at the Z pole. Cannot reach higher energies because of bremsstrahlung.

FCC-ee MDI



CLIC 3TeV



EXTRACTING DETECTOR REQUIREMENTS

The overall physics program is extensive!

- **Choose representative measurements or searches,** that are key to the e^+e^-physics program and that put constraints on the performance of one, or several, subdetectors

  - Reducing major experimental systematics uncertainties
  - Extending sensitivities/acceptance

- Ultimately, which processes set the tightest constraints on a given performance metrics will be known only when analyses are completed (interplay of reconstruction tools, backgrounds etc)

  - Different detector concepts could make different trade-offs
  - Multiple detector options allow to diversify the design

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TRACKING

LOW MASS RESONANCES (Z): stability of momentum scale constraining low p_T tracks

FLAVOUR: search for LFV decays $B_s \to \mu\mu$, $\tau \to 3\mu$

HIGGS: determination of M(H) from a fit to the recoil mass in $e^+e^- \to ZH, Z \to \mu\mu$

- Not only **momentum resolution**!
- **Track efficiency** at low momenta is crucial for particle flow reconstruction and for flavour measurements
- **Two-track separation:** relevant for flavour decays and tau physics ($\tau \to 5\pi$)
- Measurements with di-muons need precise determination of the **angles** $< 100\mu rad$
  - Measuring the beam energy spread, the crossing angle, the √s , etc…

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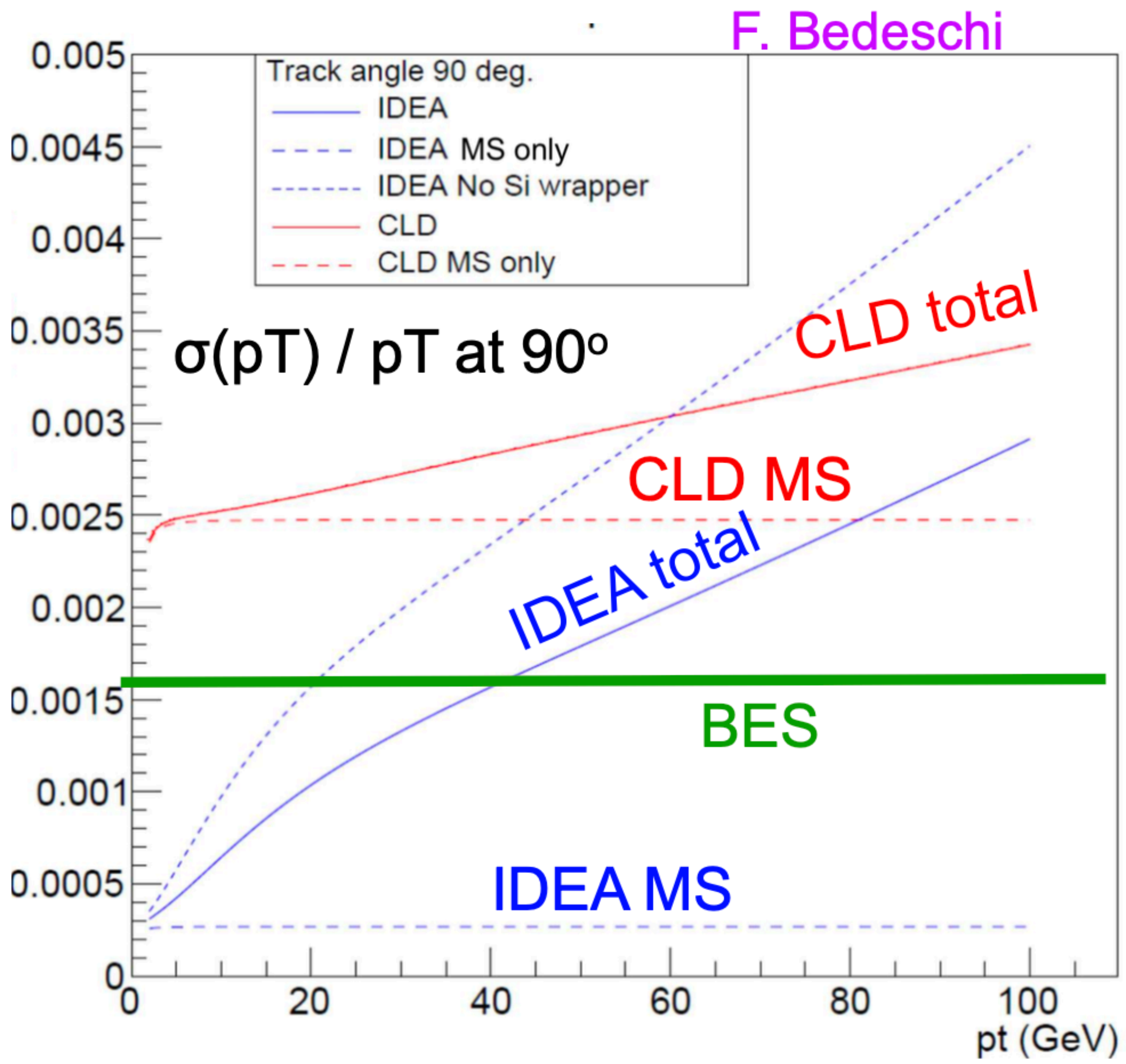
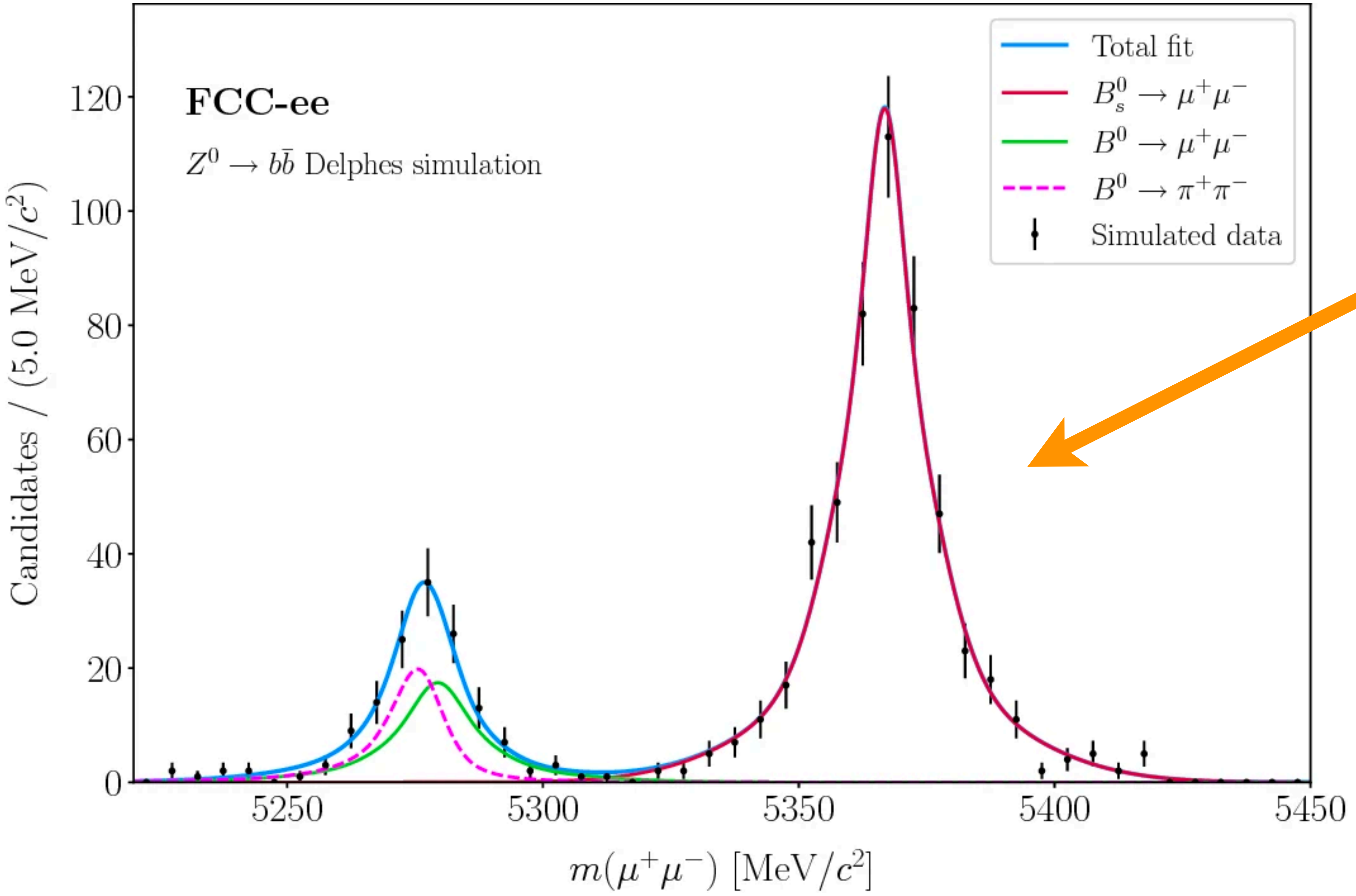
EFFECT OF BEAM ENERGY SPREAD @FCC-ee

- BES inherent to the machine:
    - for FCC-ee ~0.16% at √s=240GeV (~0.13% at √s=90 GeV)
- Track momentum resolution limits sensitivity if greater than BES
    - Ideally $\sigma_p/p \approx rel\,.\,BES$
- IDEA DCH tracker close to this limit
- CLD Full Si tracker is a bit worse. In the energy range considered the resolution is dominated by multiple scattering

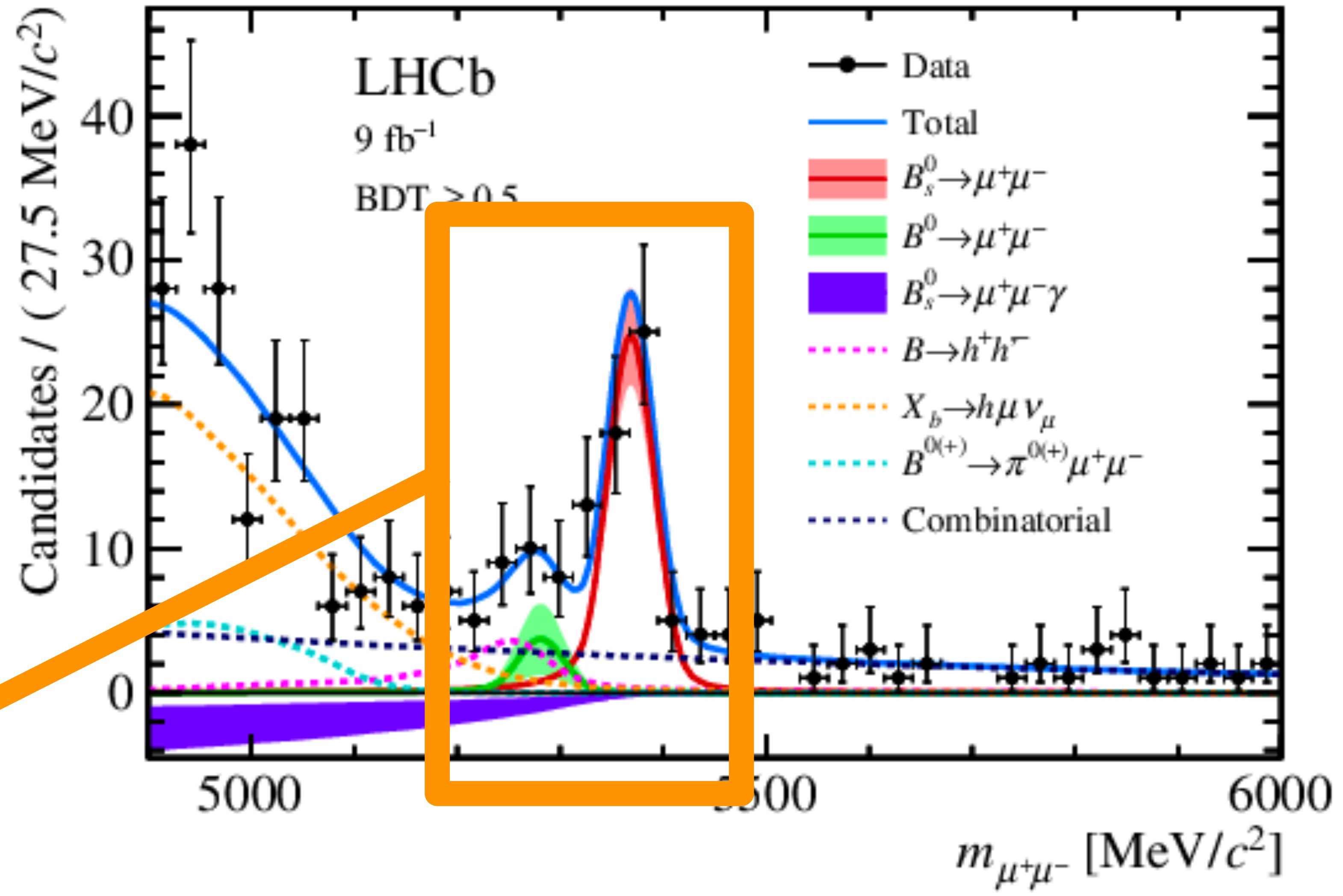


LEPTON FLAVOR VIOLATING PROCESSES: $B \to \mu\mu$

Delphes study with IDEA Drift Chamber



EPJ+ 136, 837(2021)



- FCC-ee can excel on the studies of this rare process and its properties
- Need excellent mass resolution allowing to separate the two peaks from B^0 and B_s^0
  - Other assumptions such as the $\pi \to \mu$ misidentification need to be further verified as it contaminates the peak.

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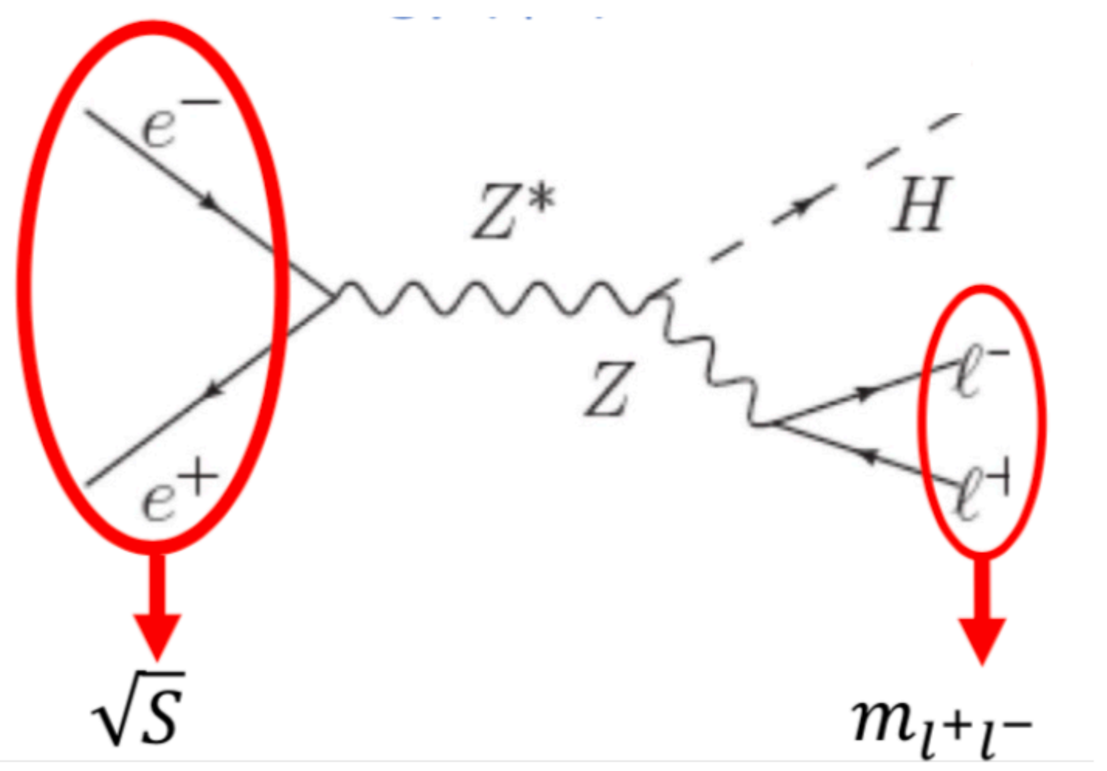
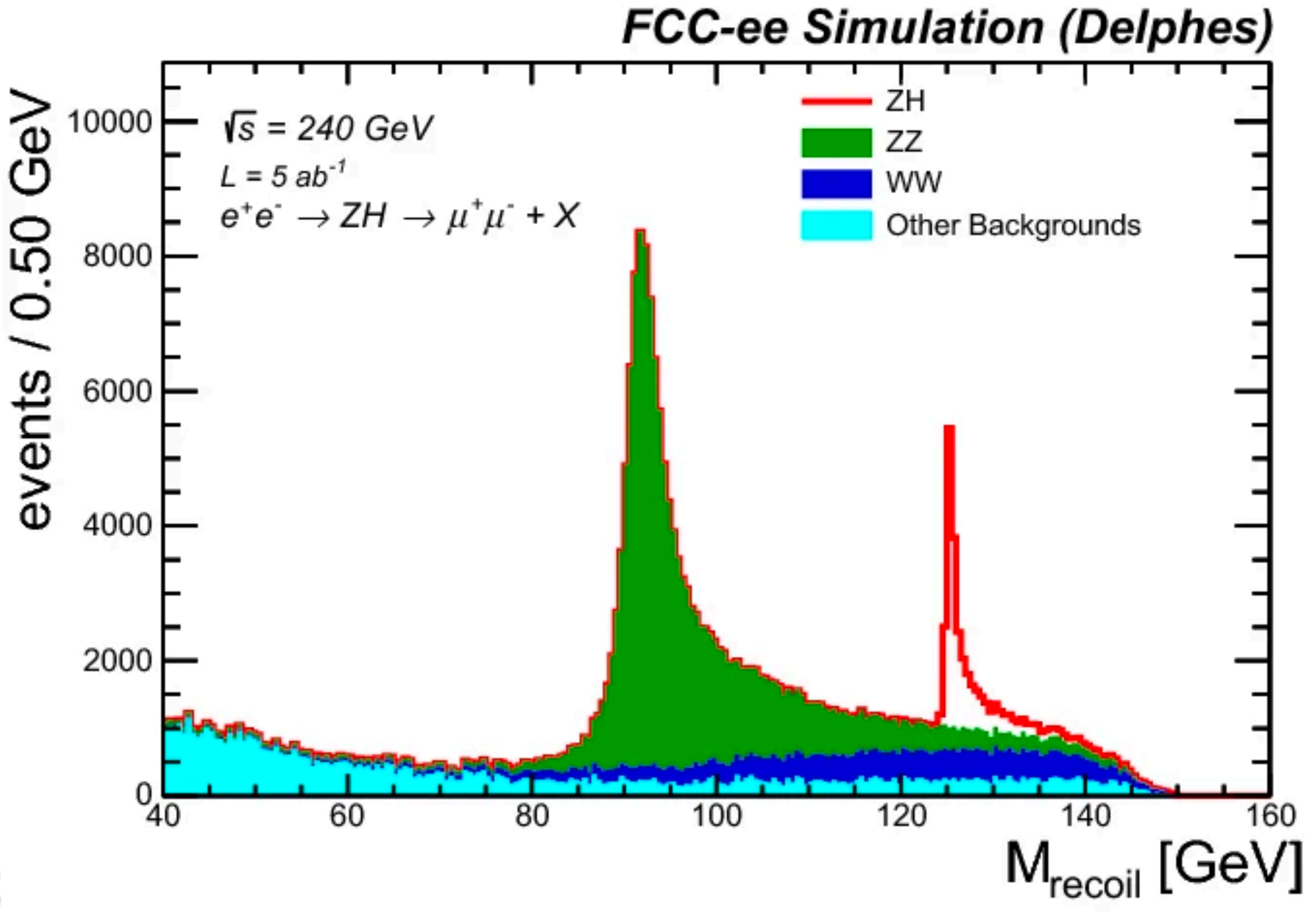
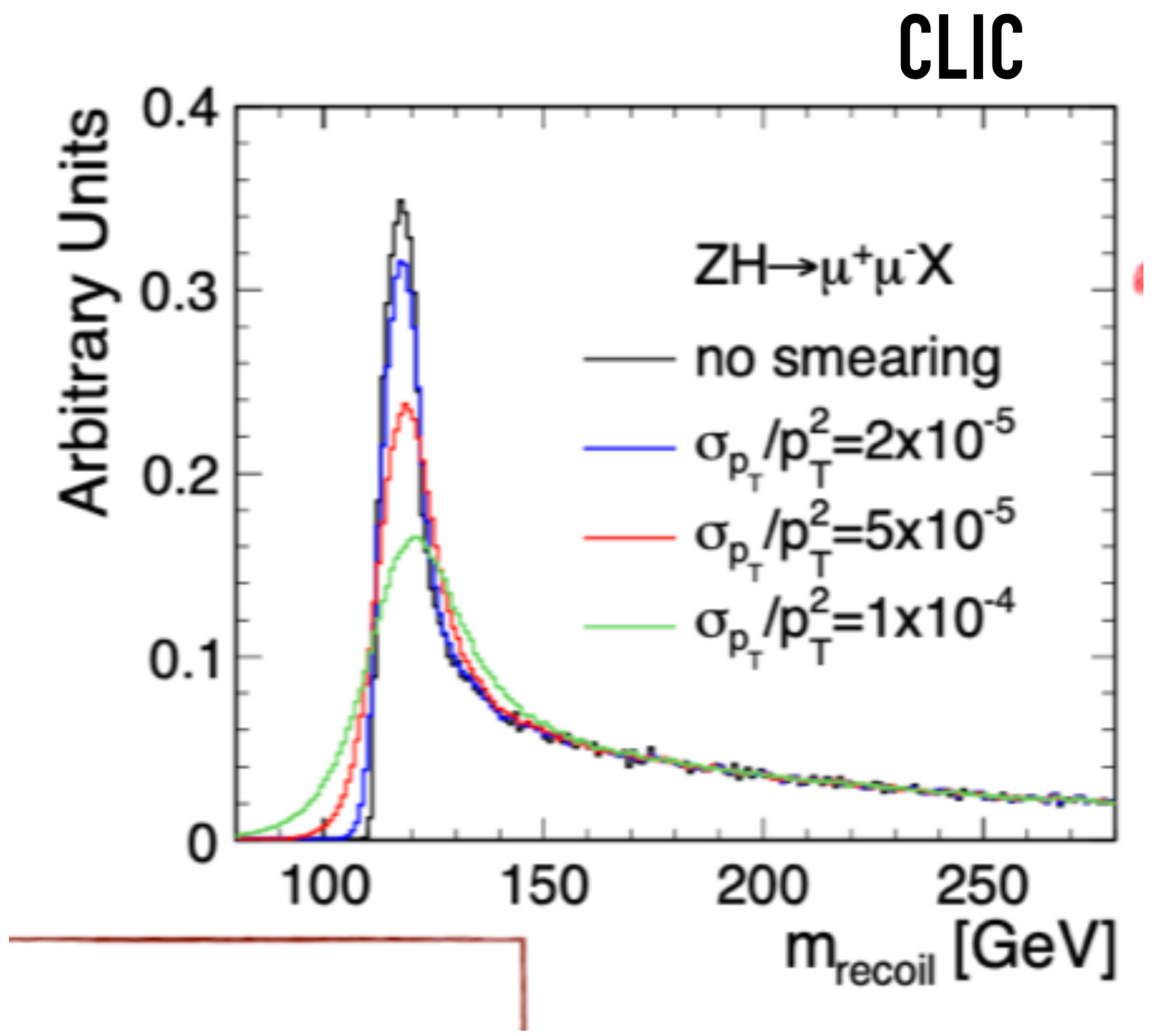
TRACKING MOMENTUM FROM HIGGS RECOIL AT √s=240/250GeV

Unique to lepton colliders: ZH events tagged by the Z

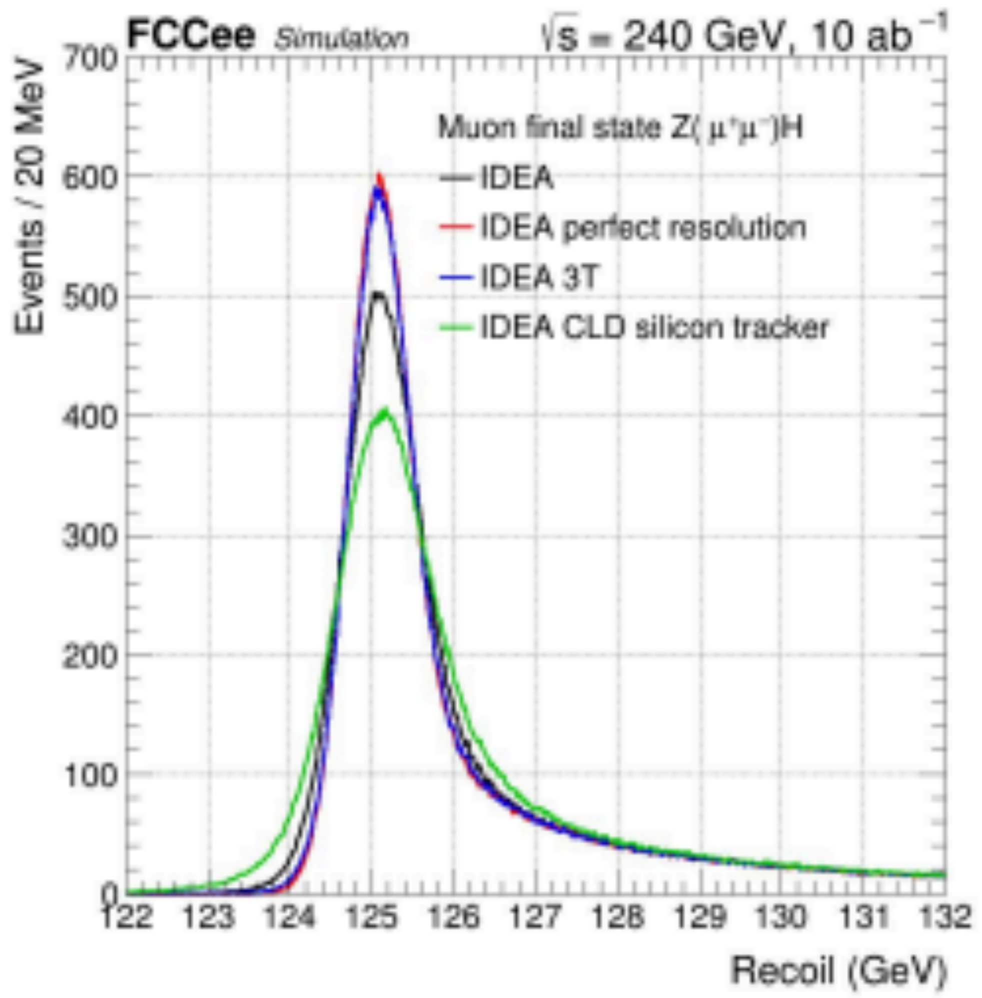


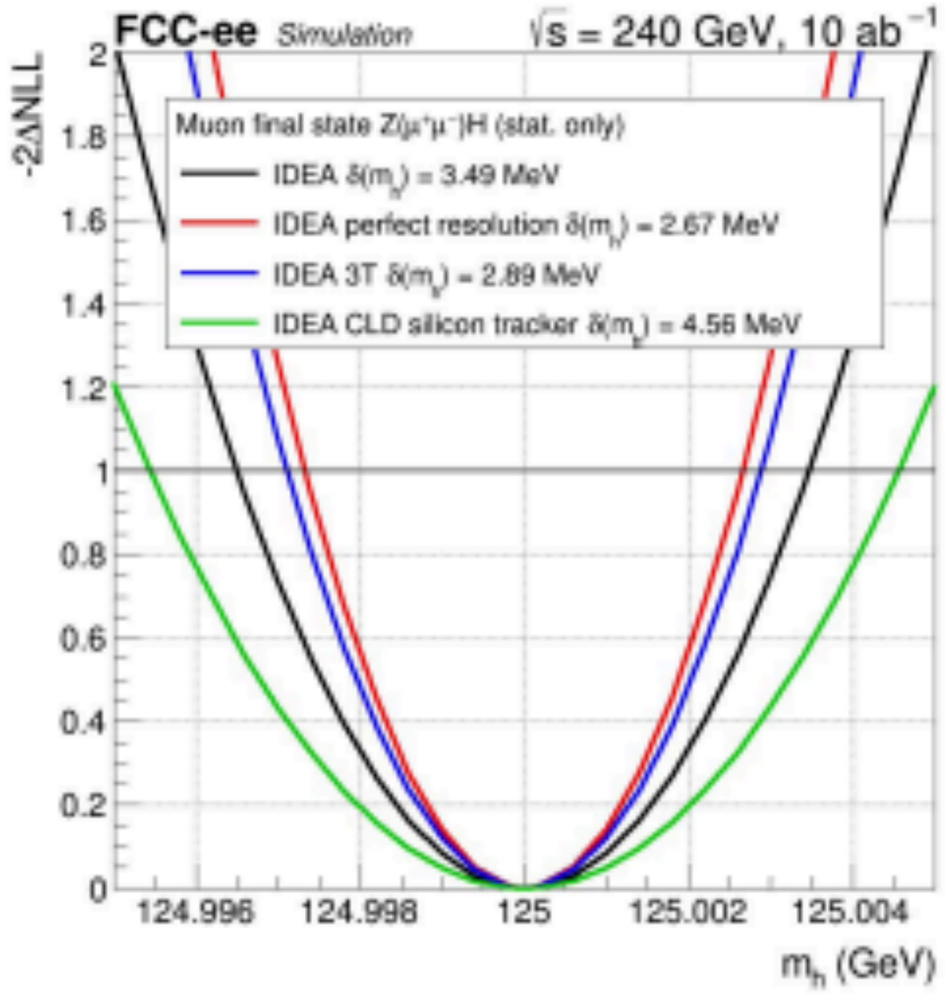
$$m^2_{\mathrm{recoil}} = (\sqrt{s} - E_{l\bar{l}})^2 - p^2_{l\bar{l}} = s - 2E_{l\bar{l}}\sqrt{s} + m^2_{l\bar{l}}$$





- Sensitivity dominated by the $Z \rightarrow \mu\mu$ final state
- Goal is $\Delta m_H \approx \Gamma_H \approx 4\mathrm{MeV}$ to allow run at √s=125 GeV for electron Yukawa determination
- Resolution $\sigma_{pT}/p_T^2 \simeq 2 \times 10^{-5}$ seems sufficient for the goal



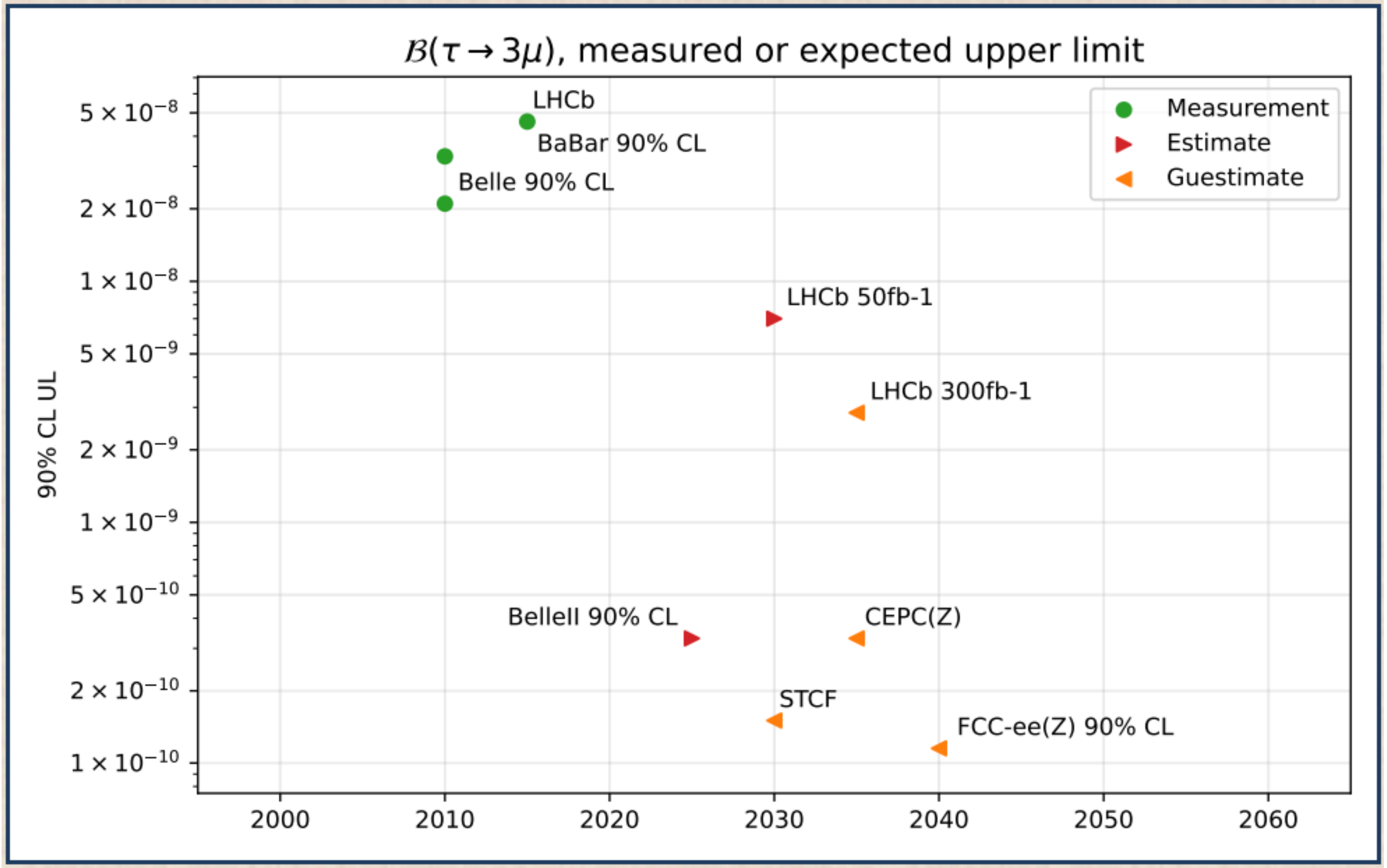


using μμ channel

tracking system	Δm_H (MeV) stat.only	Δm_H (MeV) stat + syst
IDEA 2T	**3.49**	**4.27**
Perfect	**2.67**	**3.44**
IDEA 3T	**2.89**	**3.97**
CLD 2T	**4.56**	**5.32**

A. Lusiani, FCC Week 2023

LEPTON FLAVOR VIOLATING PROCESSES: $\tau \rightarrow 3\mu$



Very relevant process for new physics search

- FCC: $8 \times 10^{12} Z^0$,2.7×10^{11} τ pairs. O(100) more than BelleII
  - estimate 4× better efficiency at FCC vs. BelleII
- If search remains background free (unlikely) the FCC 90% UL is ~0.2×10^{-10}
- If we require the candidate mass precision to be $\sigma[m_\tau(3\mu)] \leq 25\mathrm{MeV} \Rightarrow$ momentum resolution $\sigma_p/p \leq (0.02 \cdot 10^{-3} \cdot p_T(GeV) \oplus 1 \cdot 10^{-3})$
  - Of course many other assumptions come in this extrapolation.

VERTEXING

- Main purpose:
  - reconstruction of PV, SV, TV
  - low Pt track reconstruction & momentum determination
  - late decays and conversions
  - track seeding (depending on main tracker)
  - fake tracks mitigation

HIGGS: Jet flavour identification (tagging) of b-, c-, g-, tau- etc… Measure of Higgs couplings

Z: Jet flavour identification (tagging) for HF EWK observables Rb, Rc, AFB,

W : Jet flavour identification (tagging), CKM parameters V_{cb}

Pure WP for calibration

FLAVOUR: precise reconstruction of PV/SV/TV for flavour physics

e.g. time dependent CPV measurement, rare decays $B \to K^{*}\tau\tau$, τ precise lifetime measurement

BSM: long lived particle signatures

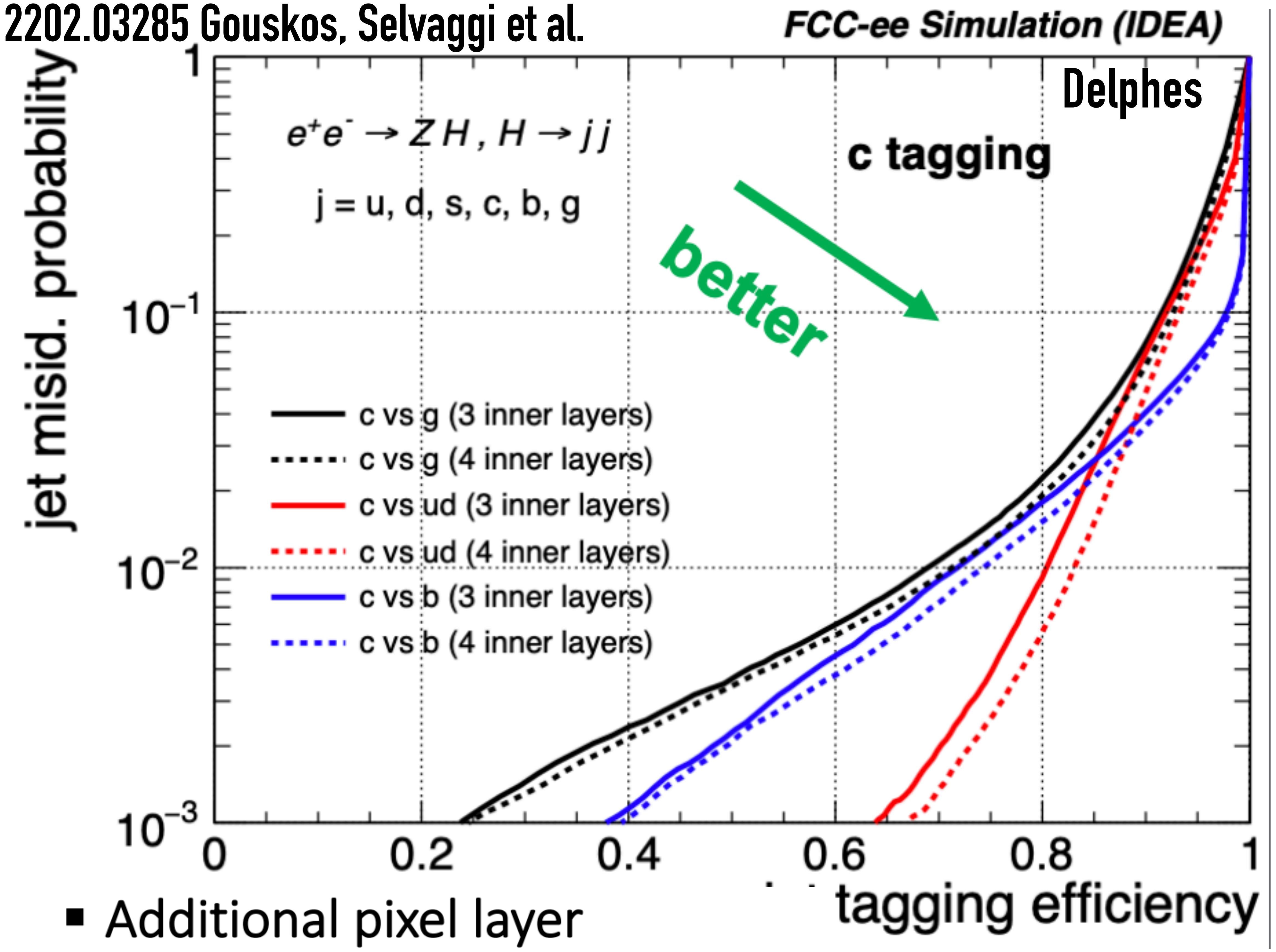
REQUIREMENTS FROM JET TAGGING

- A must for any Higgs factory
  - Precise measurement of all Higgs couplings to ff, VV
  - H(cc), H(gg) won't be measured at HL-LHC
- Flavour tagging is the key
  - Algorithms (for CC and LC) based on state-of-the-art advanced Neural Networks
  - Evolving to include taus and more…
- Requirements on Detector:
  - Position of innermost layer of vertex as close as possible to the beam pipe.
    - Also smaller beam pipe
  - Particle ID capabilities (timing?)

Few microns resolution needed on $\sigma(d_0)$

Requirements from tagging charm and more (s, tau) stricter than bottom

ParticleNet 2202.03285 Gouskos, Selvaggi et al.

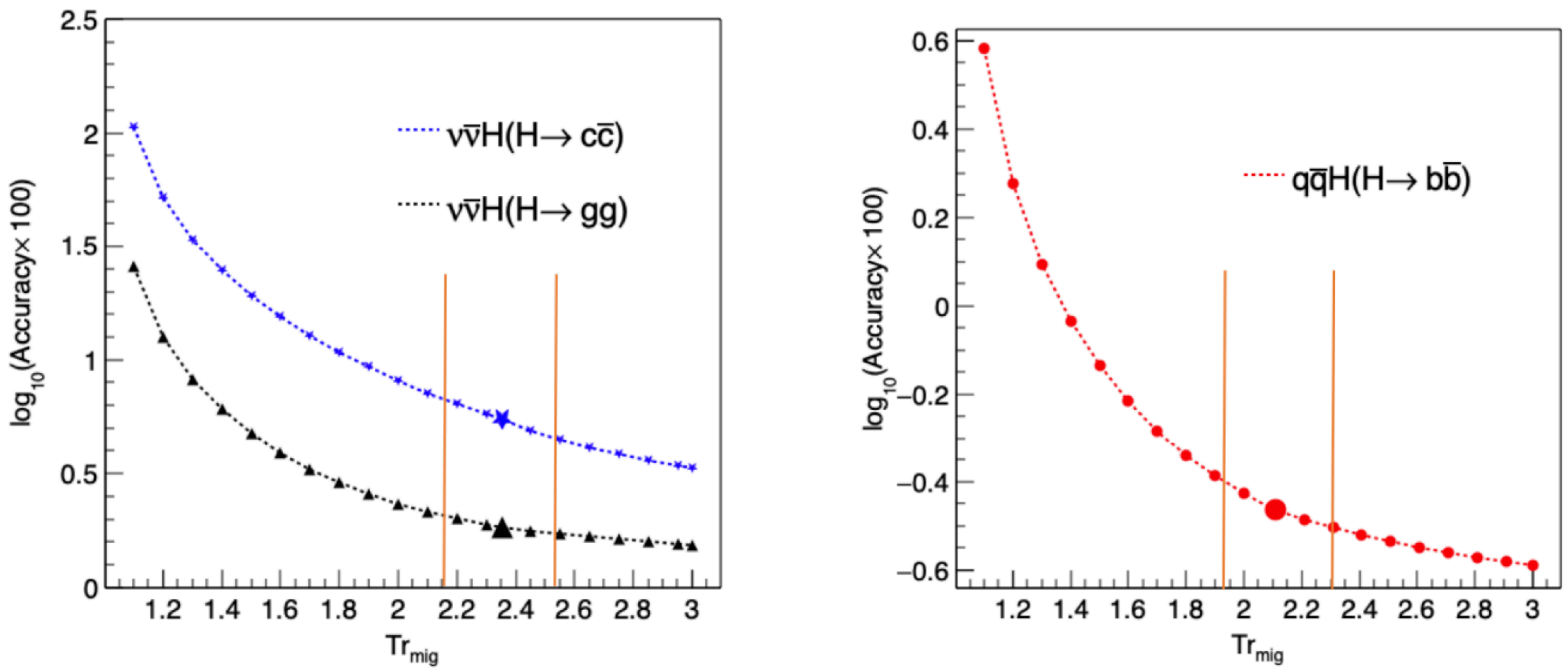


- Additional pixel layer
  - c-tagging: 2x improved BKG rejection
  - marginal/no improvement in b-tagging

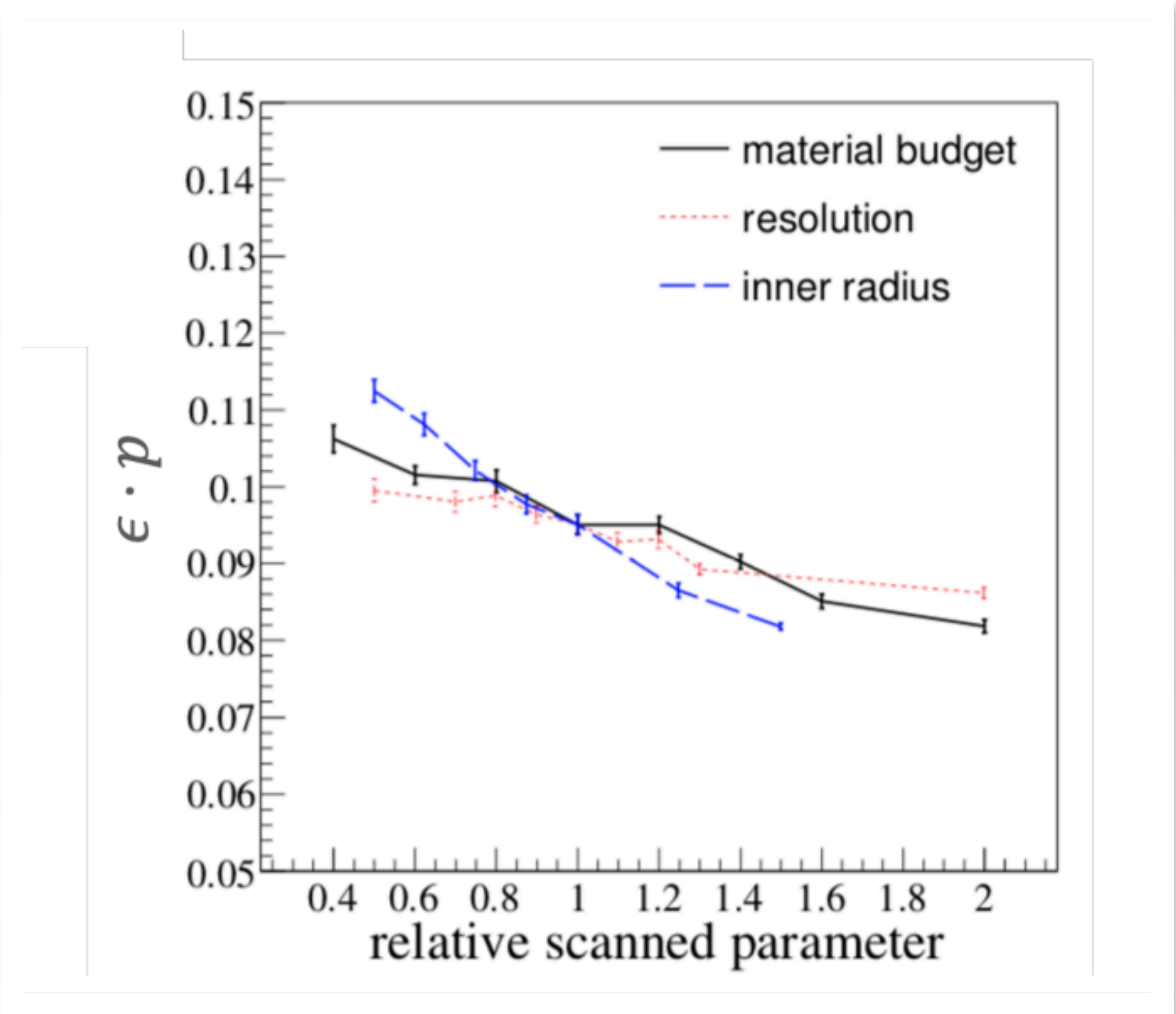
Relevant at Z, WW, top and higher energies

JHEP11(2022)100 CEPC

REQUIREMENTS FROM HIGGS HADRONIC



Variation of precision on signal strength as a function of detector parameters

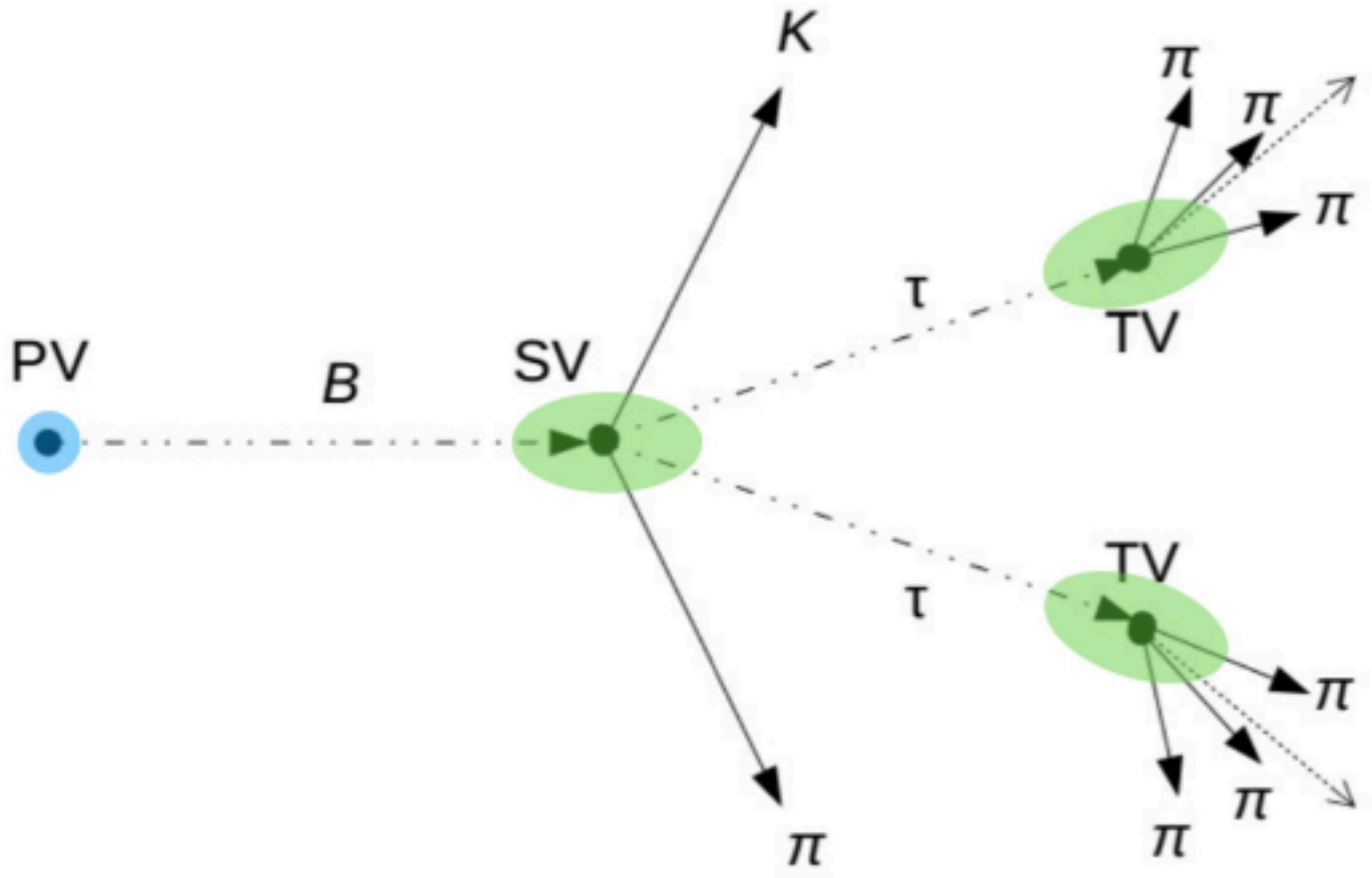


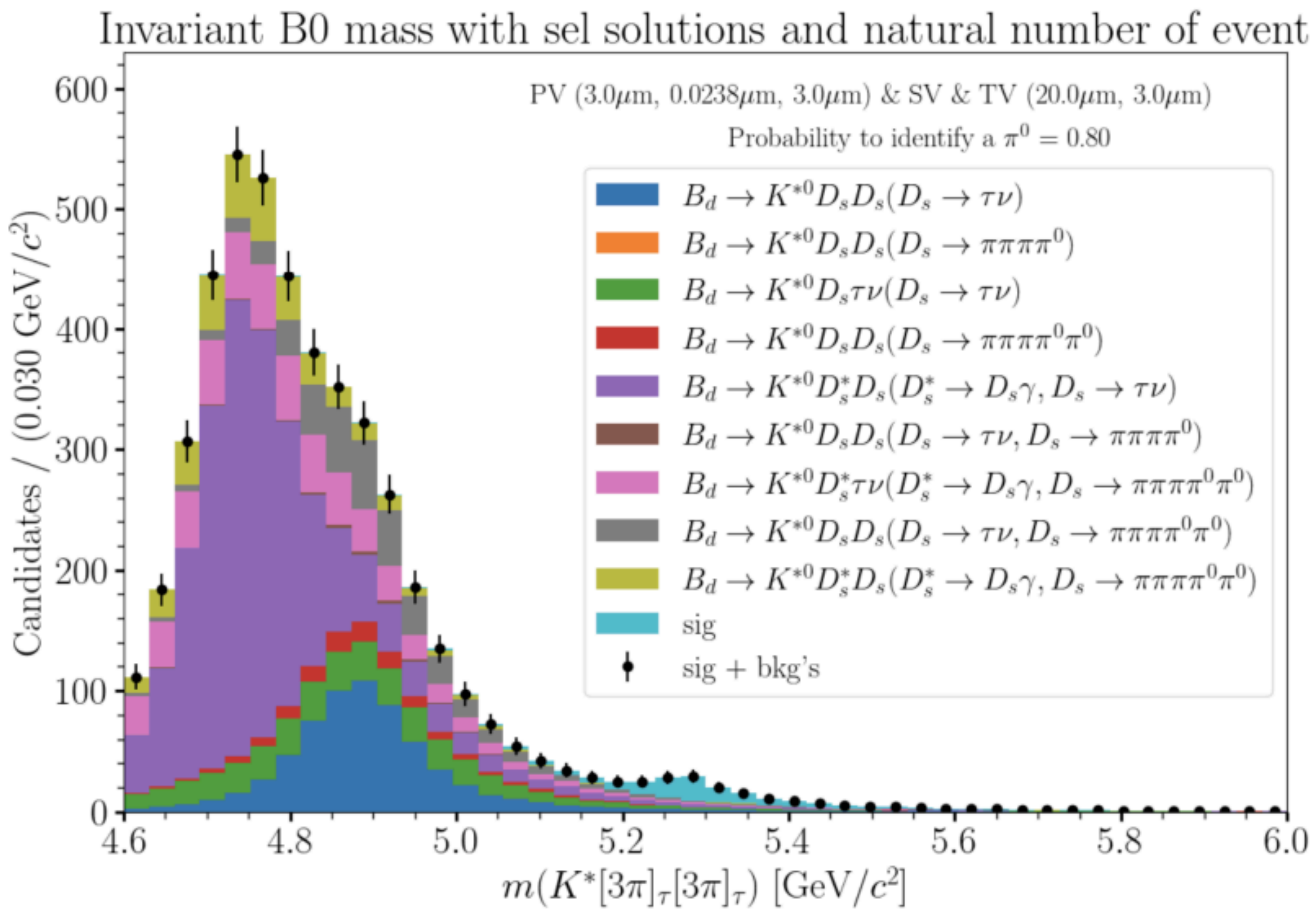
- A study of the variation of precision on signal strength as a function of detector parameters, such as material budget, single hit resolution and radius of the 1st layer.
- Conclusions: the uncertainty on the μ for $H \rightarrow b\bar{b}$ and $H \rightarrow \tau\tau$ does not exhibit a strong dependence compared to the baseline settings.
- However, μ for $H \rightarrow c\bar{c}$ does improve a lot moving the first layer closer to the beam pipe, more than any other contribution.

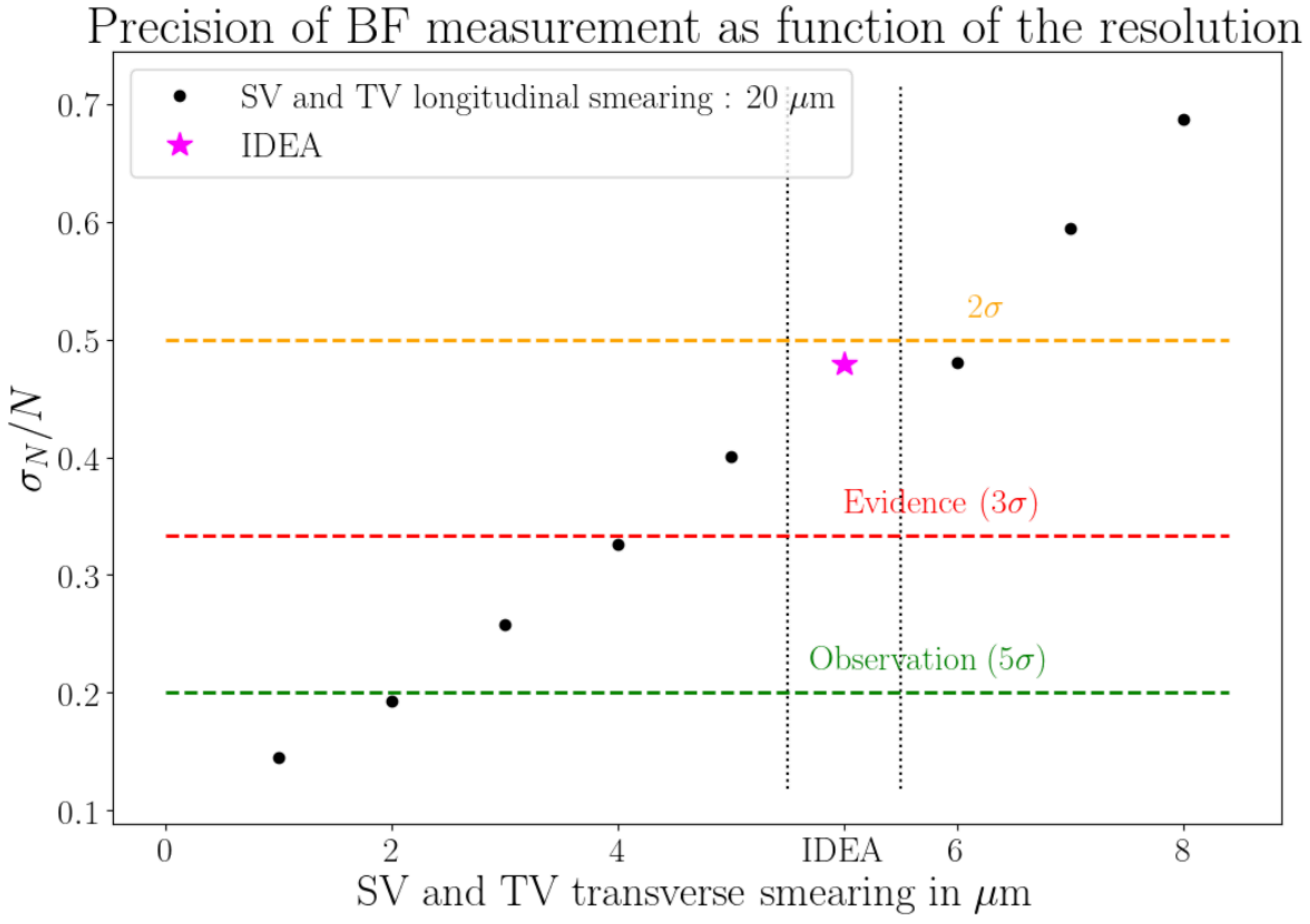
M. Ruan ECFA Tracking Workshop 2023

REQUIREMENTS FROM $B \rightarrow K^{*}\tau\tau$

- $B \rightarrow K^{*}\tau\tau$ is an important LFU test in $b \rightarrow s$ transitions
  - Focus on the 3-prong τ decays
- Very complex analysis with a very rich signature:
  - 8 visible particles (1K, 7π)
  - 1 secondary vertex and tertiary vertices
  - Many backgrounds & combinatorics: need BDT for selection



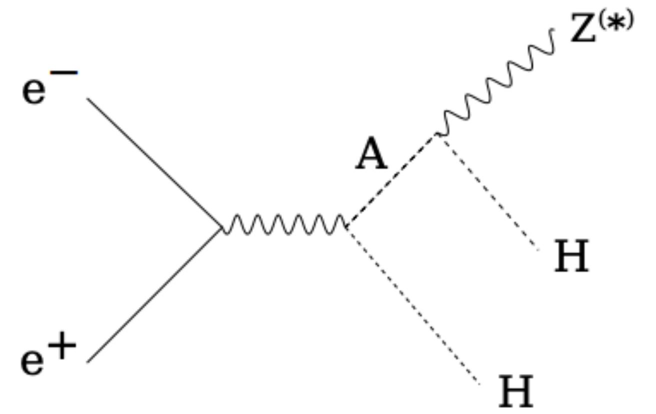




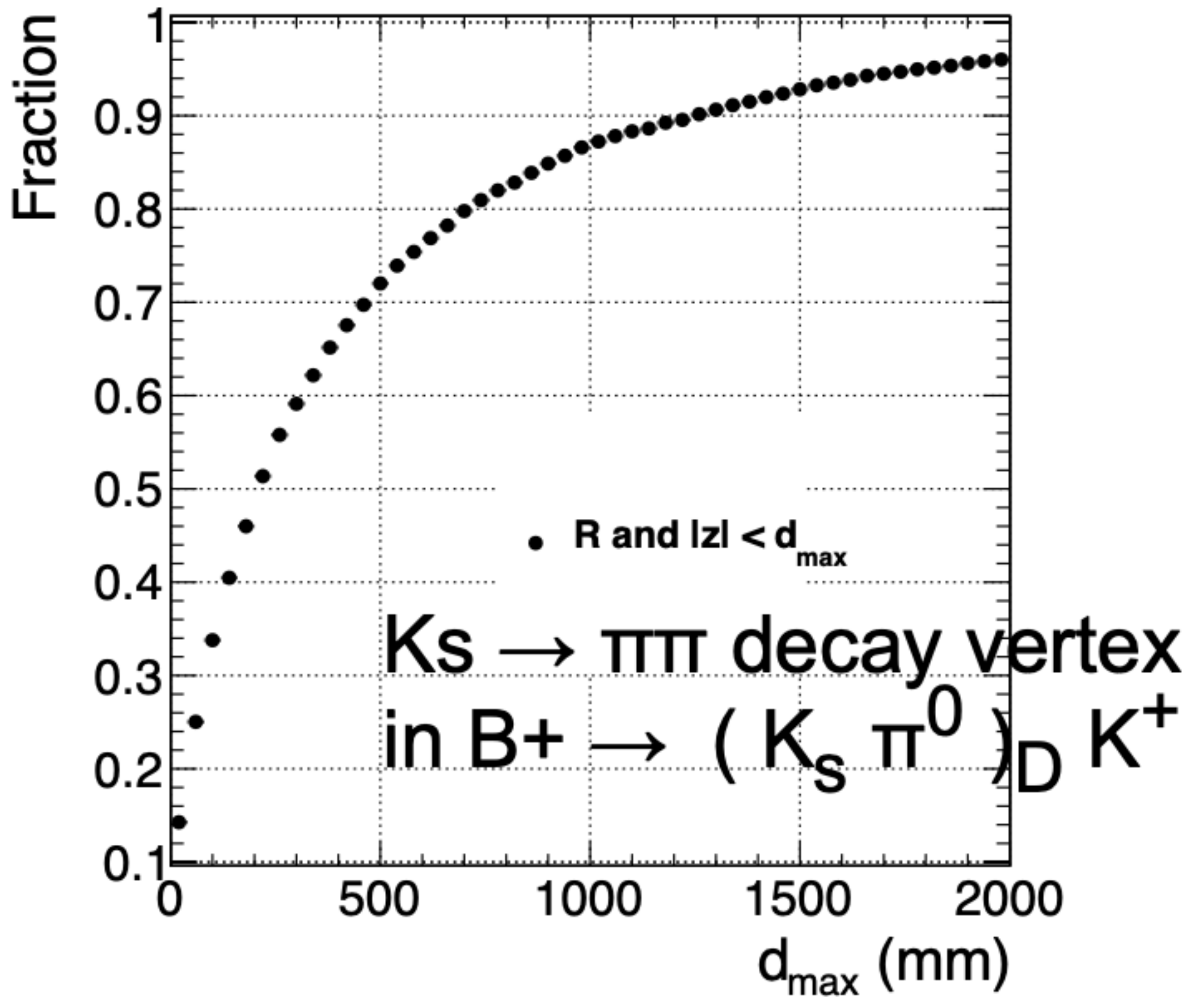
T. Miralles FCC Week 2023

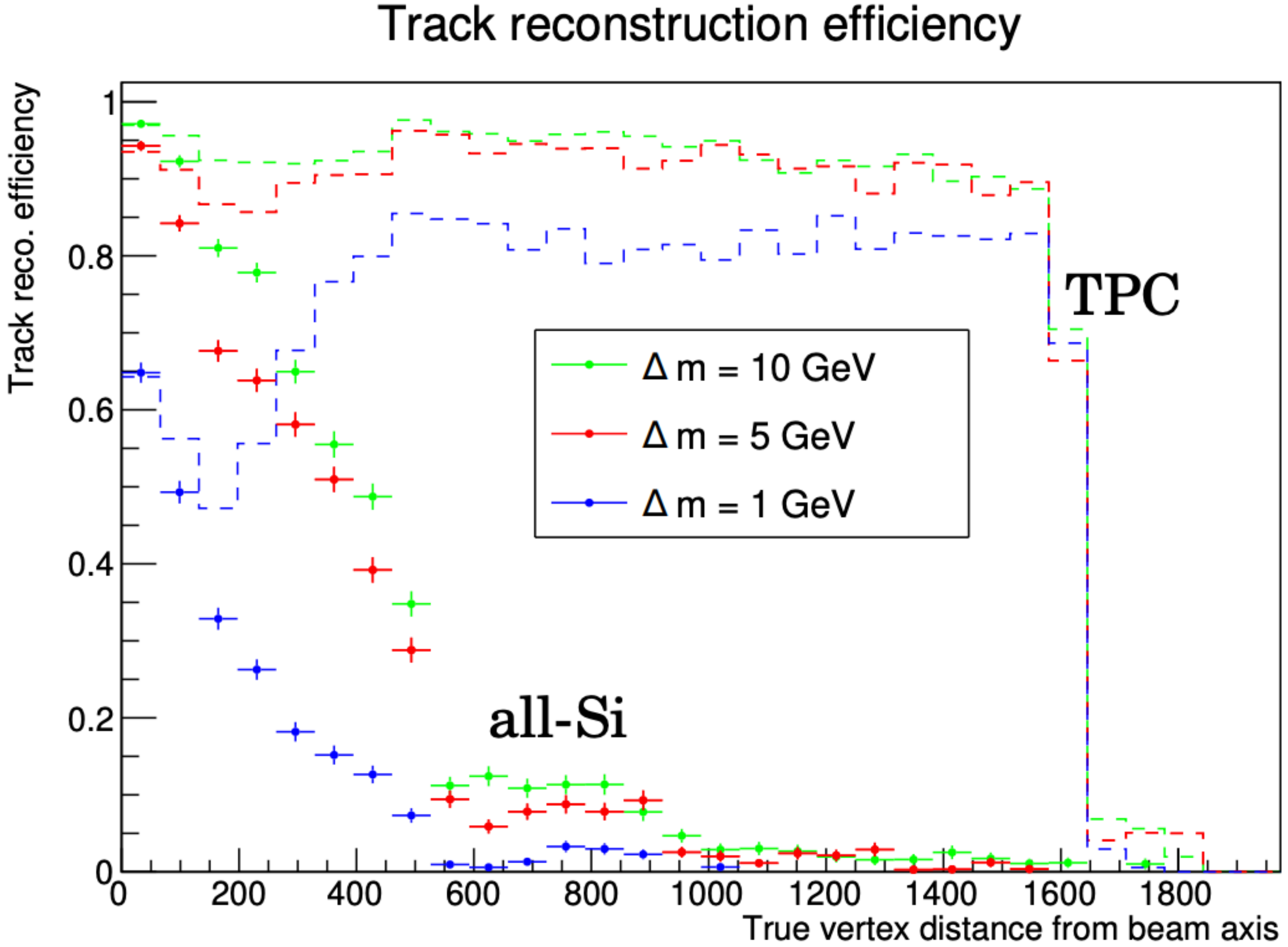
REQUIREMENTS FROM VERY DISPLACED VERTICES

- Benchmarks concerning far detached vertices up to ~1m (or more!):
  - K_S or Lambdas (relevant for B-physics but also for strange-tagging)
  - BSM processes with long lived particles (LLP), e.g. HNL, exotic Higgs decays etc.
- Needs: a large tracking volume, “continuous” tracking (that is many points/layers)
  - Maybe timing for slow moving particles (Work in progress)



30% of the K_S decay at > 50 cm from the IP



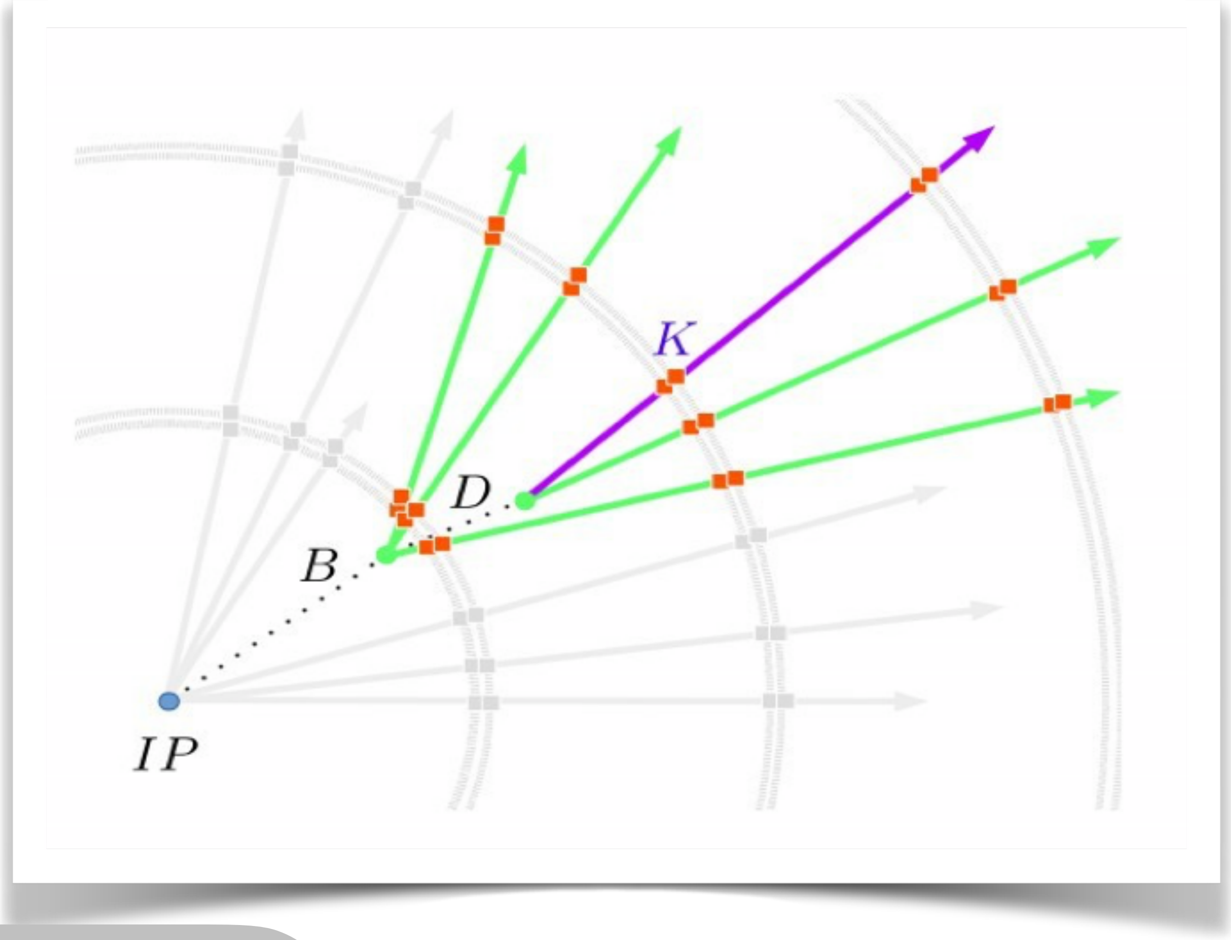


Study comparing TPC and all-Si option in ILD **Klamka, LCWS 2023**

EPJ+(2021)136:835

PARTICLE IDENTIFICATION

- PID is crucial in several contexts:



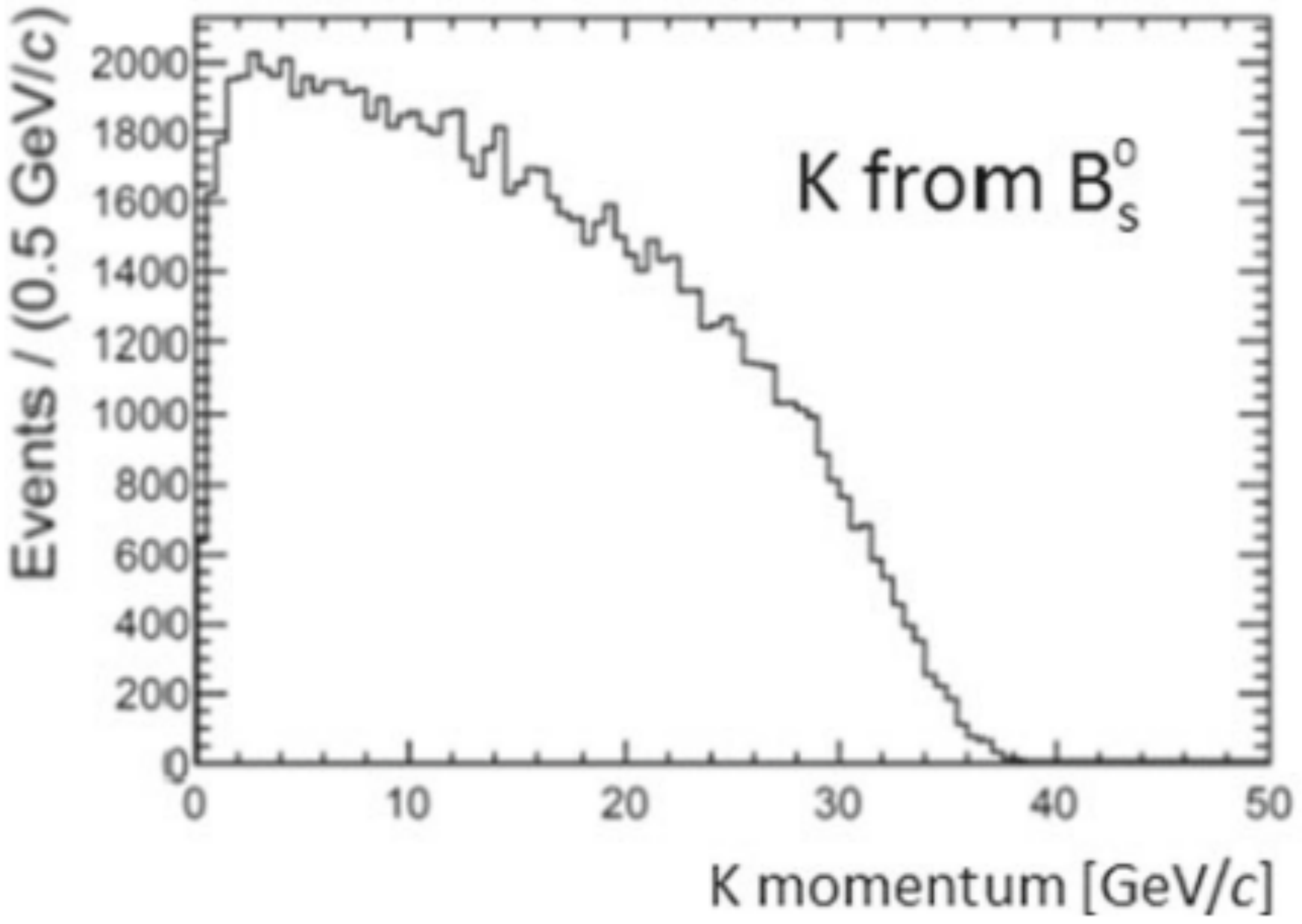
Z/W/H/t: Input to jet flavour tagging to include strange quarks (Asymmetries, CKM, Higgs hadronic decays)

FLAVOUR: background suppression - flavour "tagging" in time-dependent CP asymmetries - tau physics, e.g. $B(\tau \rightarrow \nu\pi)B(\tau \rightarrow \nu K)$

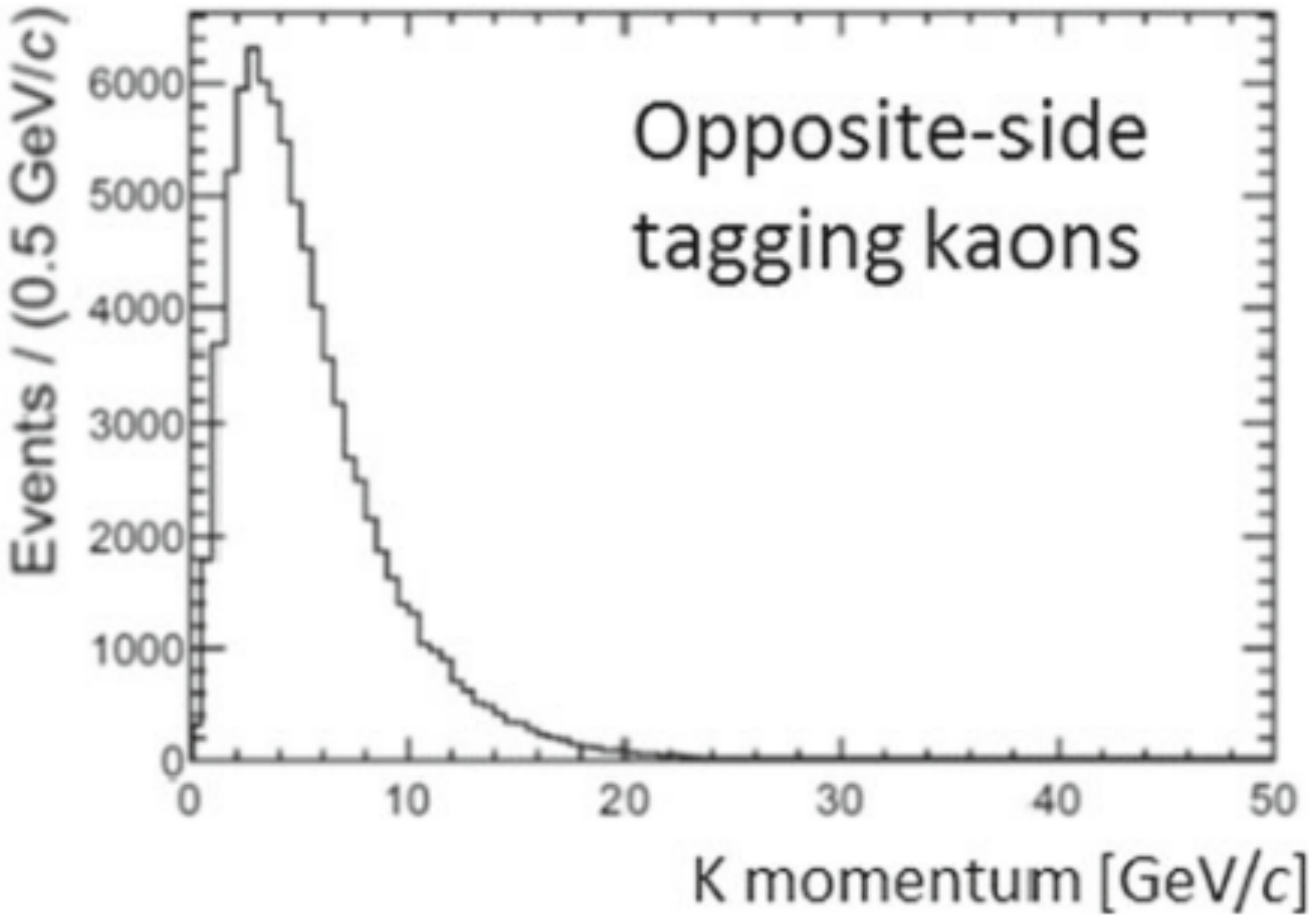
Helps with track refit with correct particle mass for better momentum and vertexing

- Needed over a large momentum range:

FROM HIGH MOMENTUM TRACKS



DOWN TO SOFT ONES



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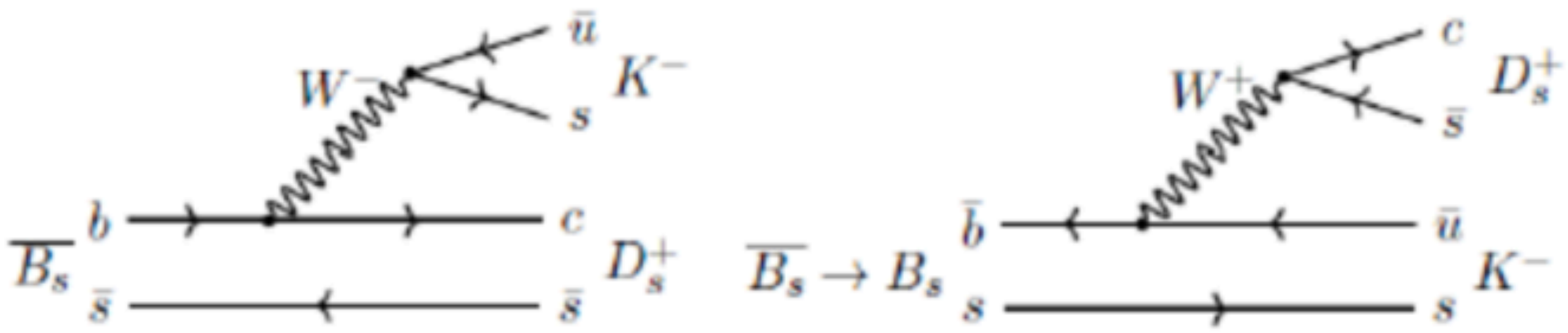
TIME-DEPENDENT MEASUREMENT OF $B_s \to D_s K$

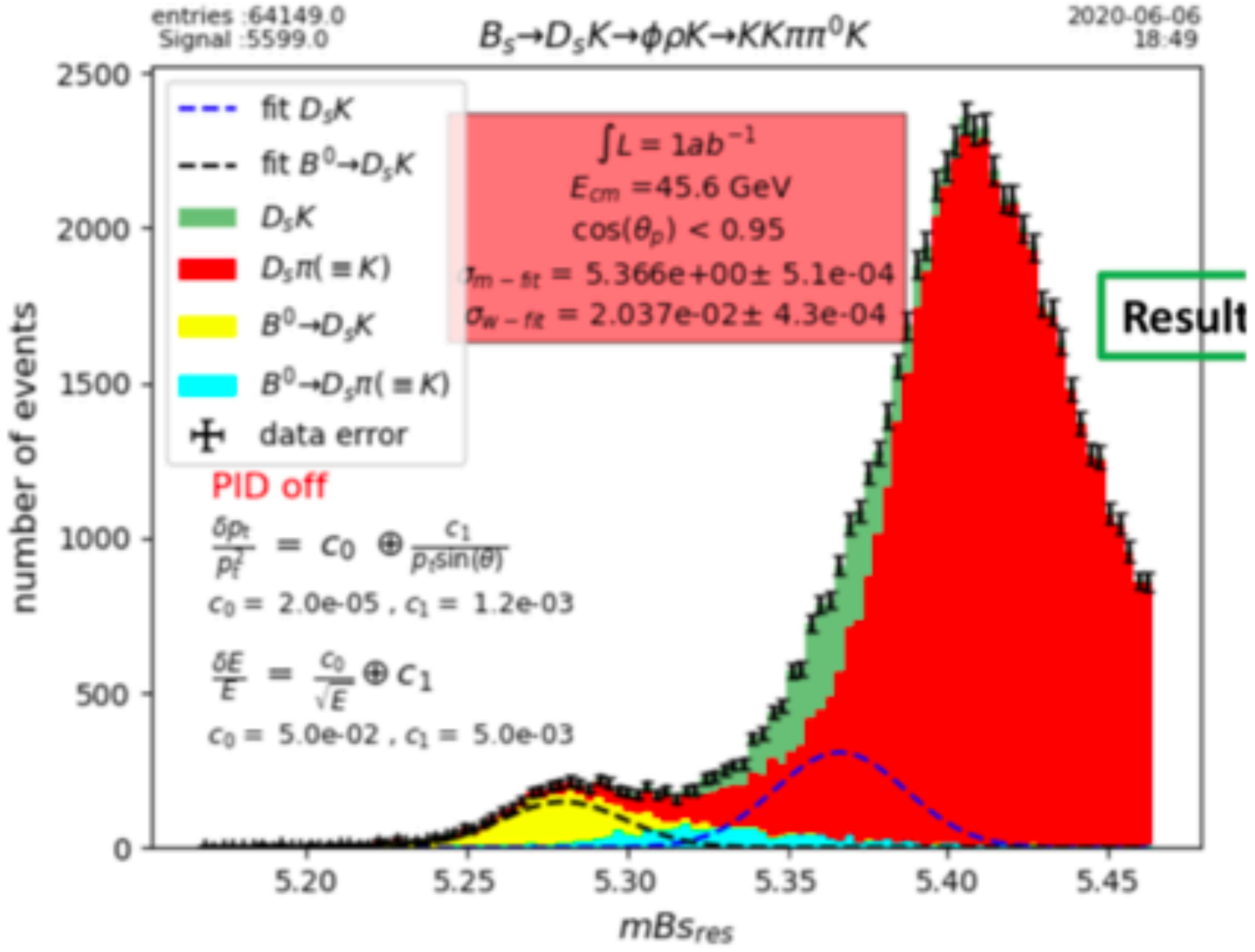
R. Aleksan et al. arxiv:2107.02002

CPV from the interference of mixing and decay, allows determine the γ angle of the usual unitarity triangle

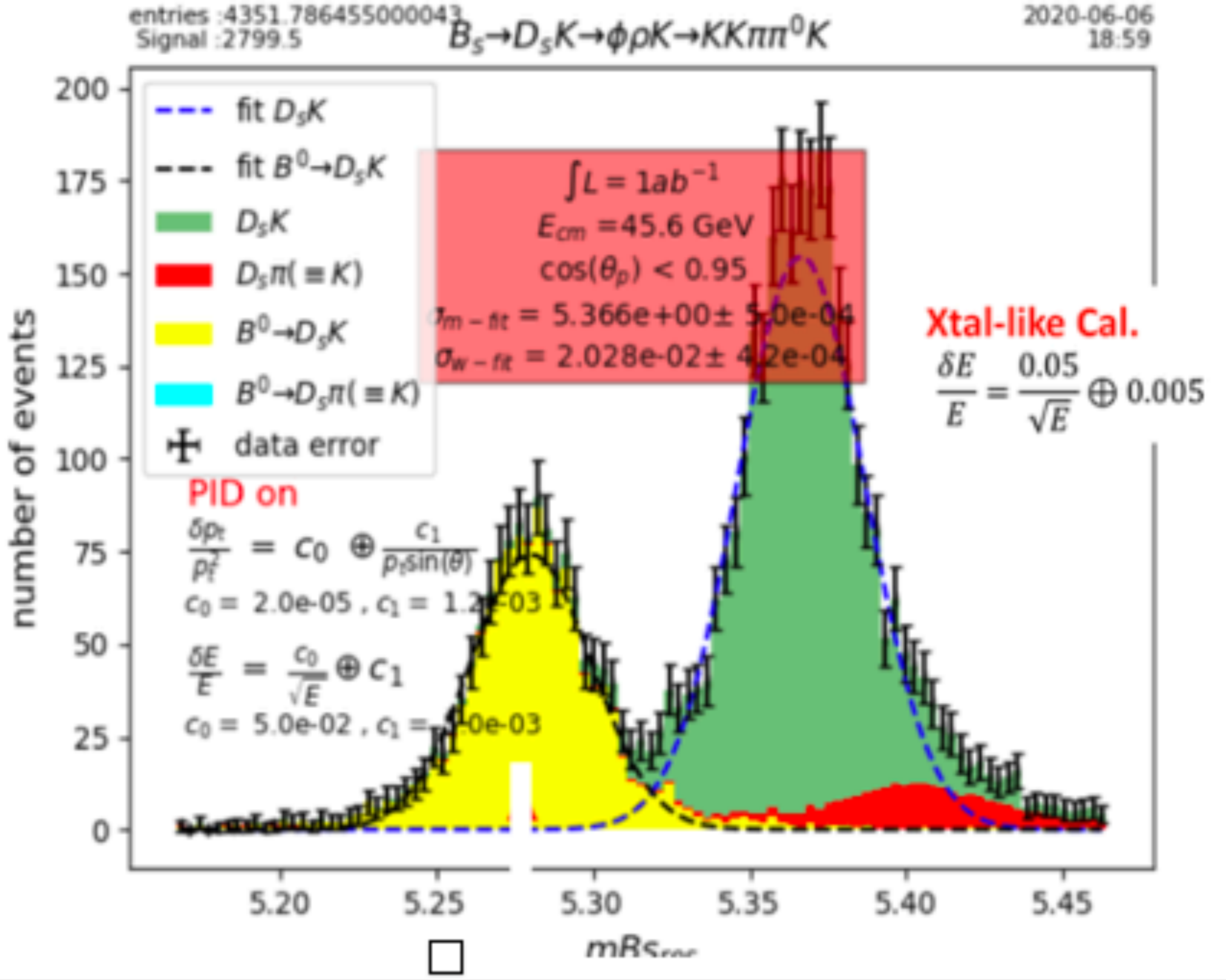


FCC-ee: Stat precision on γ = O(0.5 deg), 10x better than current

Very good ECAL, no PID



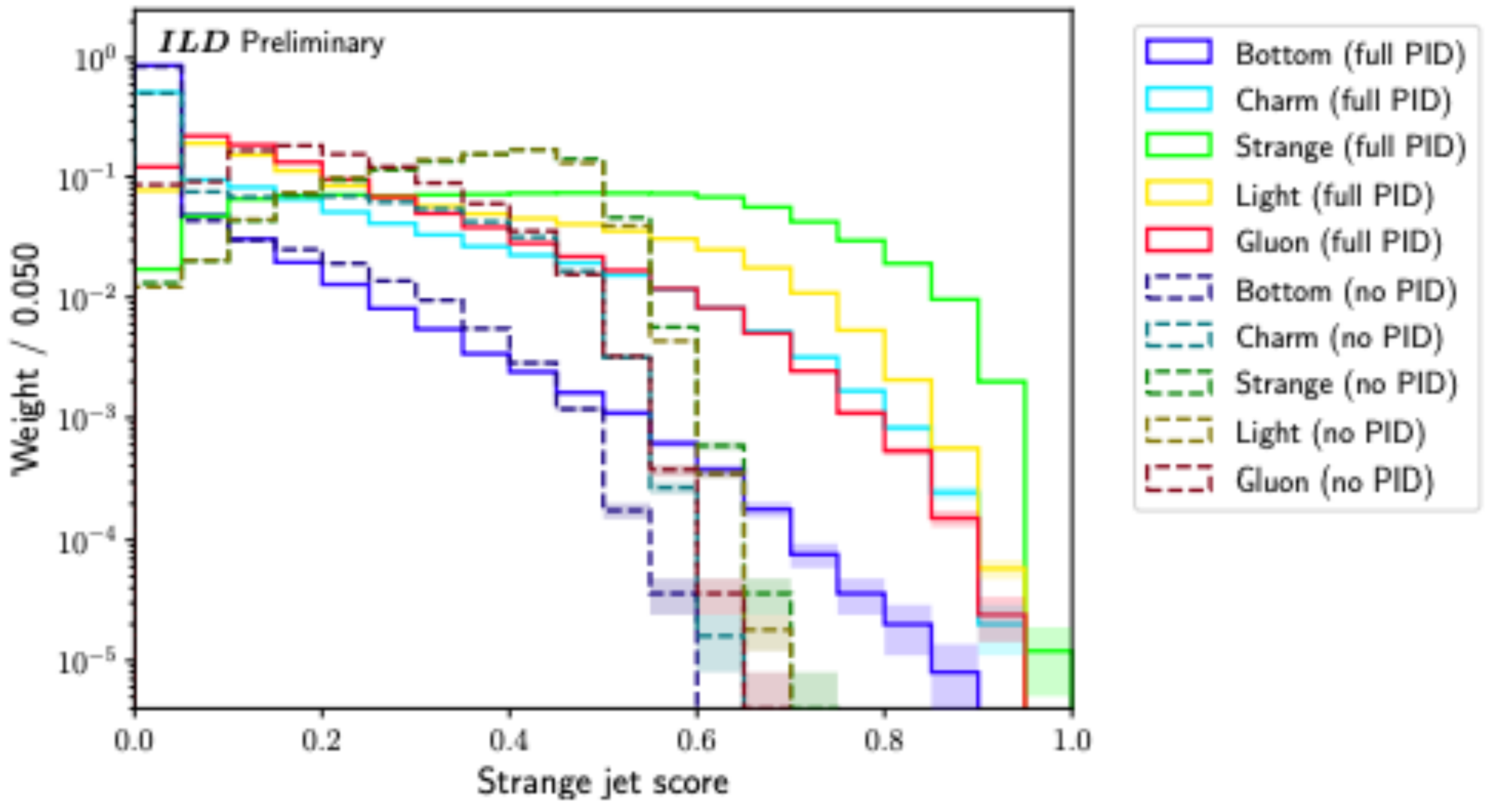
With “standard” PID



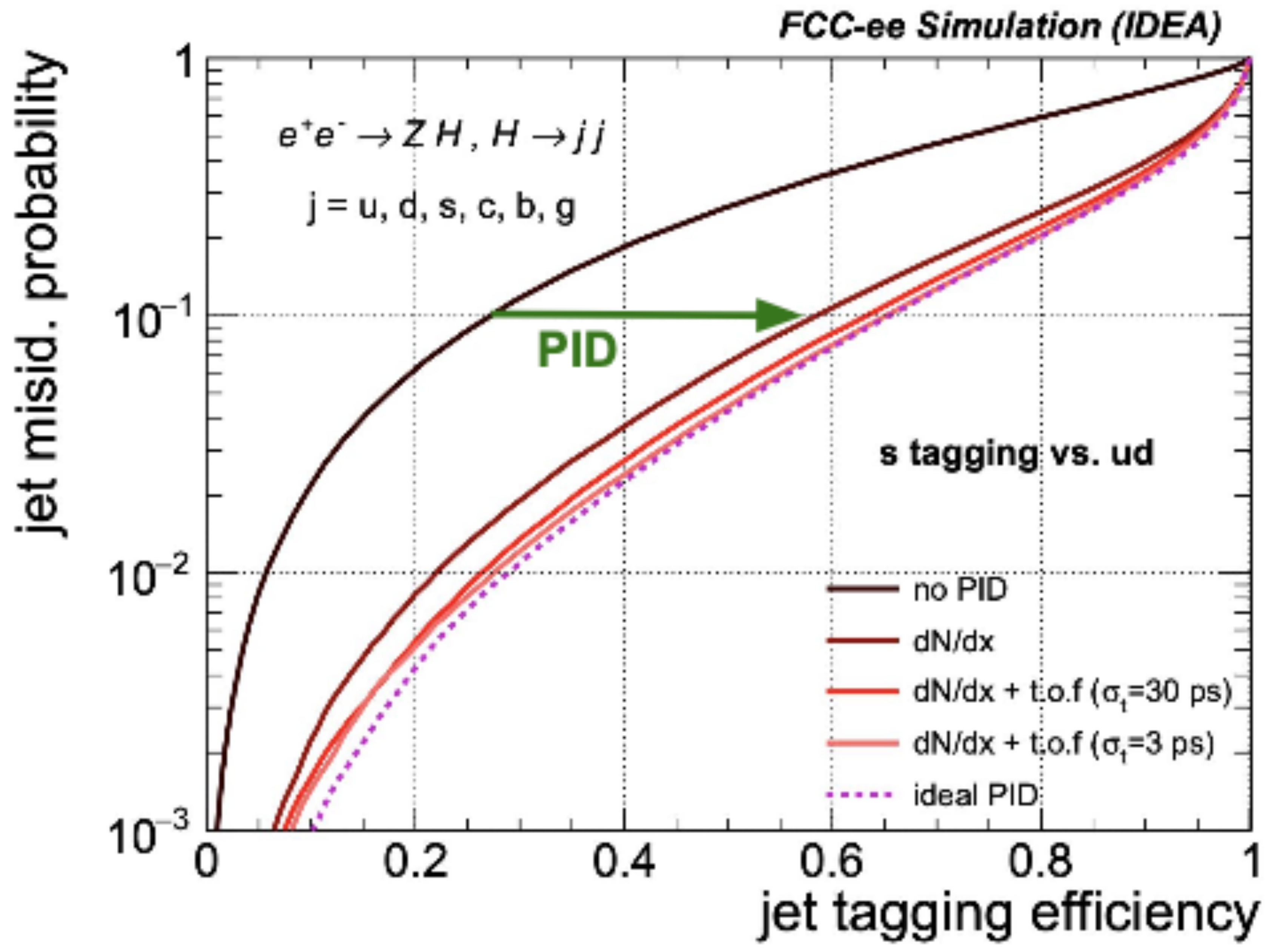
- Background $B_s \to D_s \pi$
- PID mandatory when $D_s \to neutrals$
- More bkgds to be considered. Further studies might indicate tighter requirements

2203.07535

REQUIREMENTS FROM STRANGE TAGGING



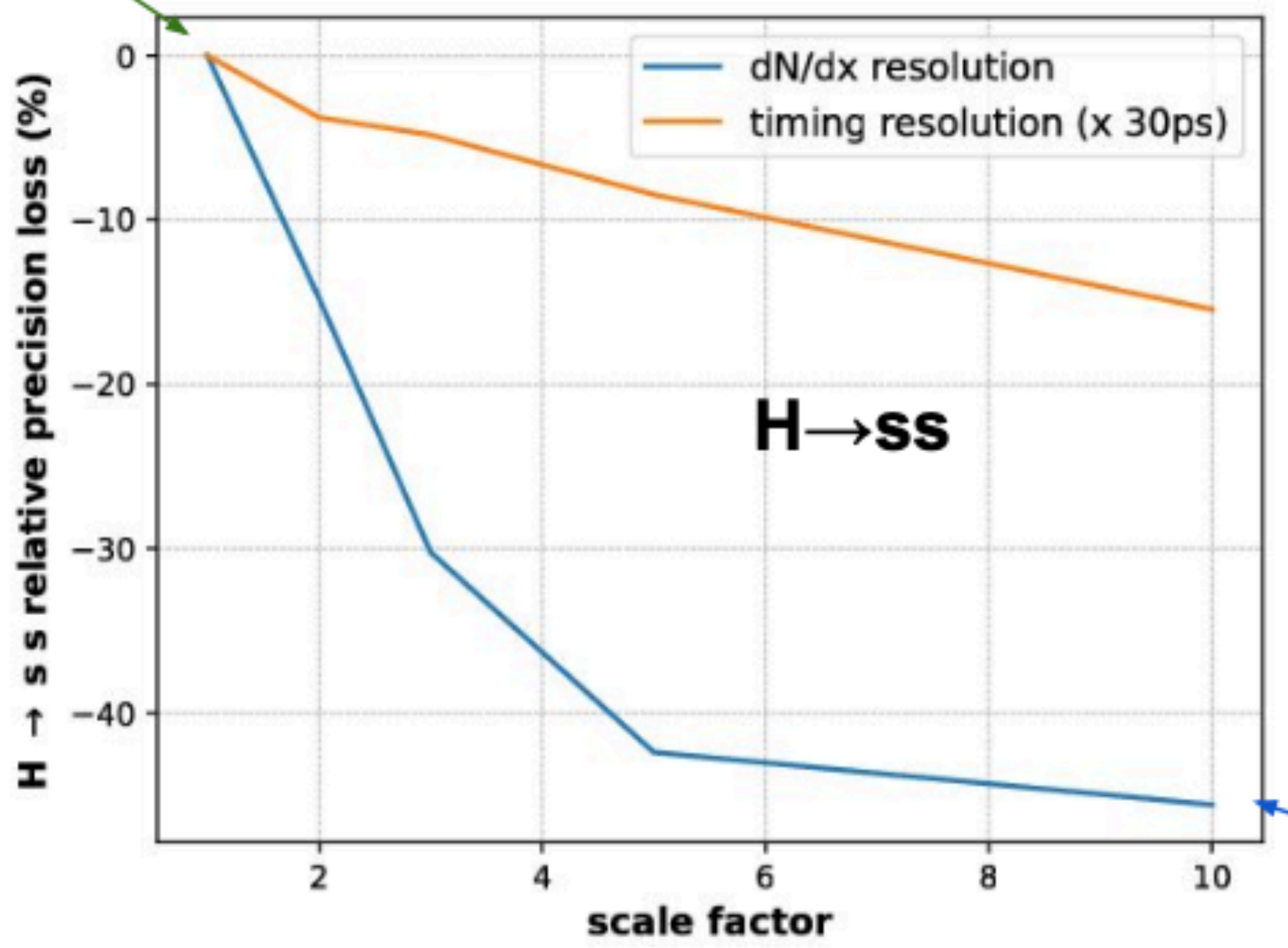
(c) *s*-jet score



New opportunity that arised…prompted new ideas on the detector side

expected precision on BR(H→ss) ~100%
with 10 ab^{-1} (only using ννH channel)

PID performance: **dN/dx > timing** resolution



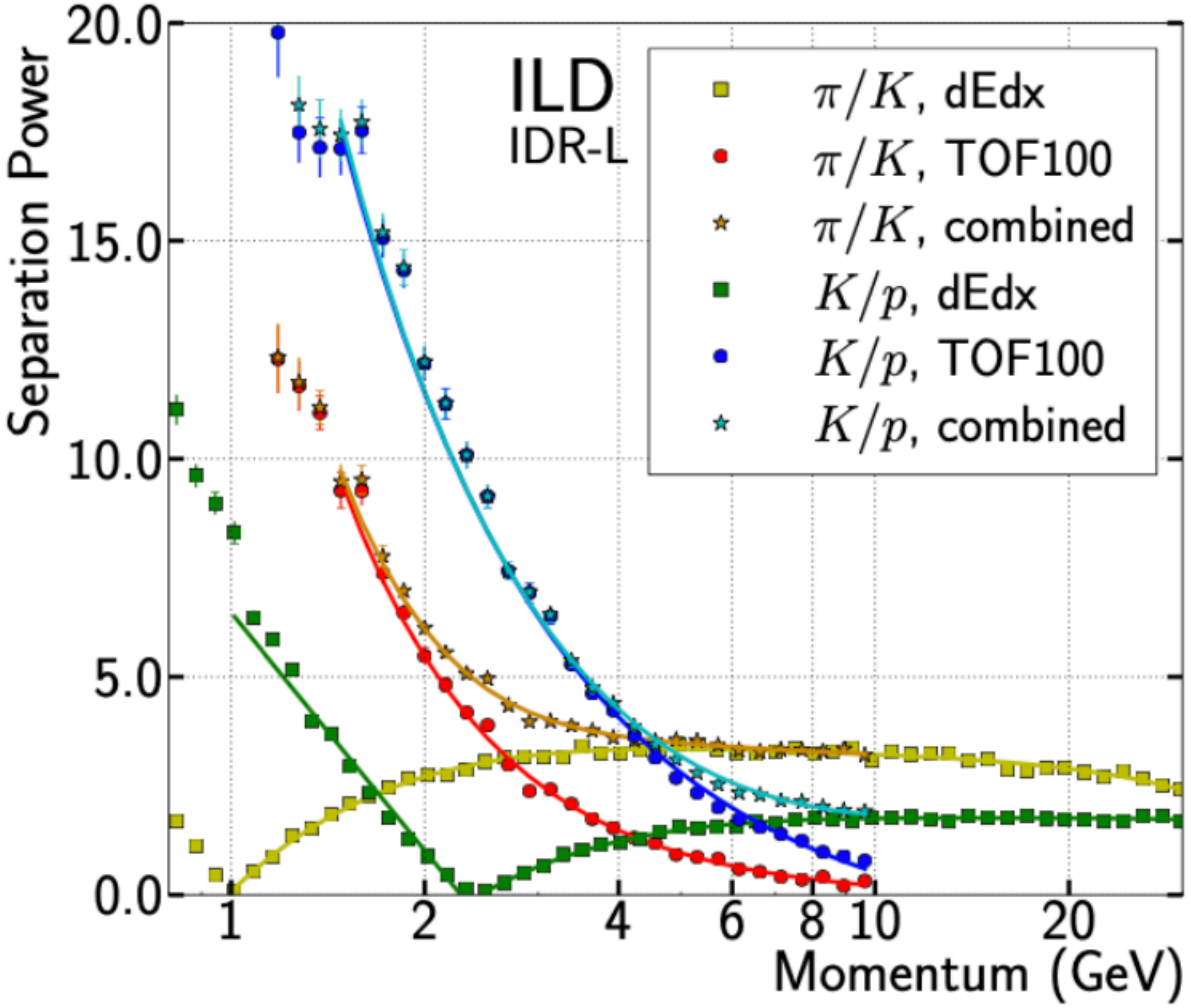
Nominal performance
$\delta\mu(Hss) = 100\,\%$

Degraded dN/dx resolution
$\delta\mu(Hss) = 140\,\%$

- $W \to cs$ decays very important high purity benchmark
- V_{cs} measurement (now at 1%)potentially to 10^{-4} @FCC-ee . To be studied as ECFA focus topic

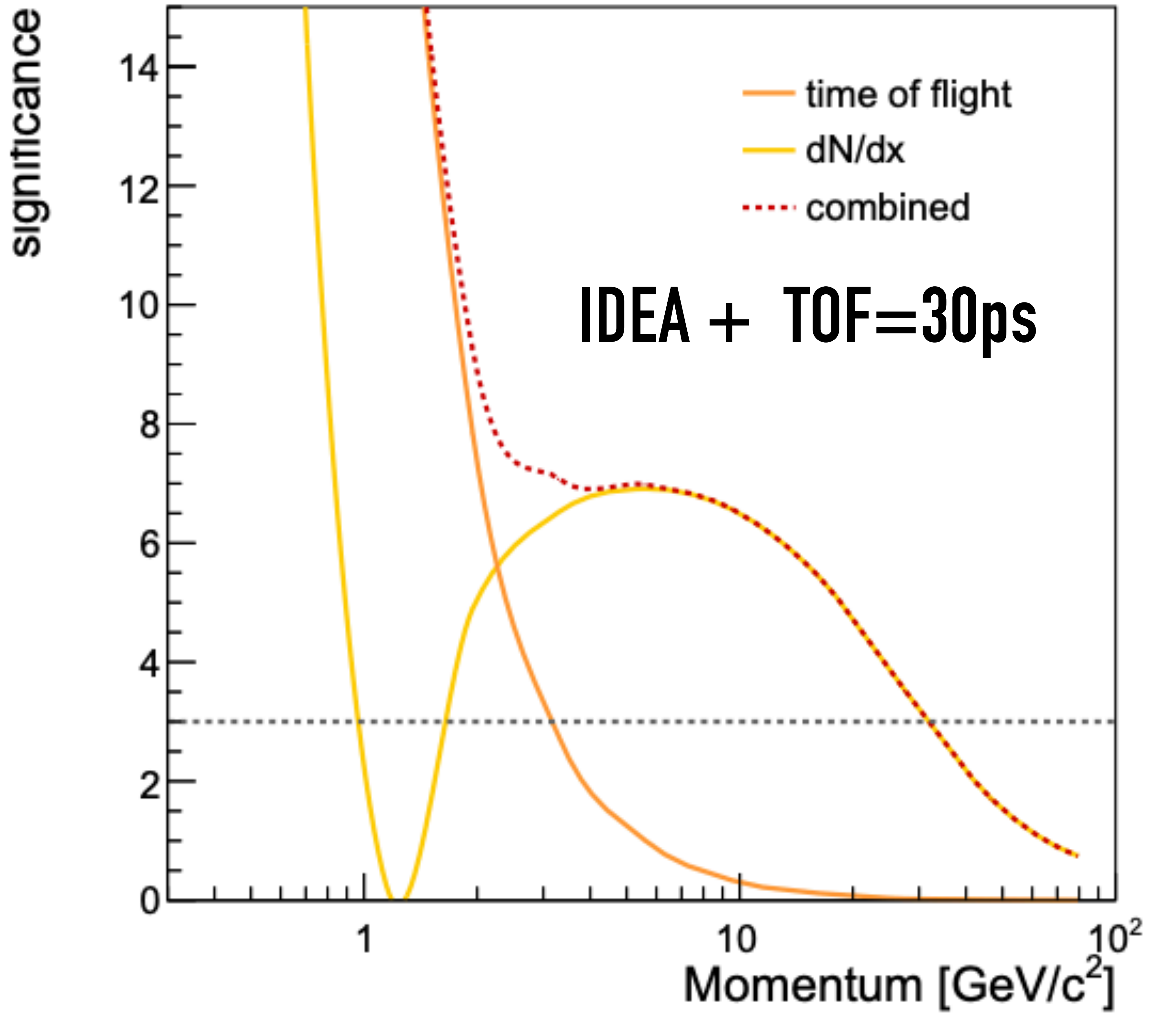
THE ROLE OF TIMING

Uli Einhaus ECFA Simulation Workshop 2023



10 ECAL layers with 100 ps

Bedeschi et al Eur. Phys. J. C 82, 646 (2022)



IDEA + TOF=30ps

- Adding TOF information (30-100ps) to dE/dx or dN/dx (cluster counting) PID methods allows a continuous π/K separation at more than 3σ in the kinematic range of interest: from low momenta up to ~30GeV.
- The advantages of having timing information in the context of e^+e^- colliders are a hot topic now for physics and detectors design.

ELECTROMAGNETIC CALORIMETER

- energy resolution and calorimeter granularity (transverse and longitudinal segmentation) very important for precise reconstruction of low energy photons and pions (flavour and tau physics)
- Important input to EM objects in jets (e.g. $H \to gg$)

HIGGS: $H \to \gamma\gamma, H \to Z\gamma$, HZ recoil with $Z \to ee$ brem. recovery

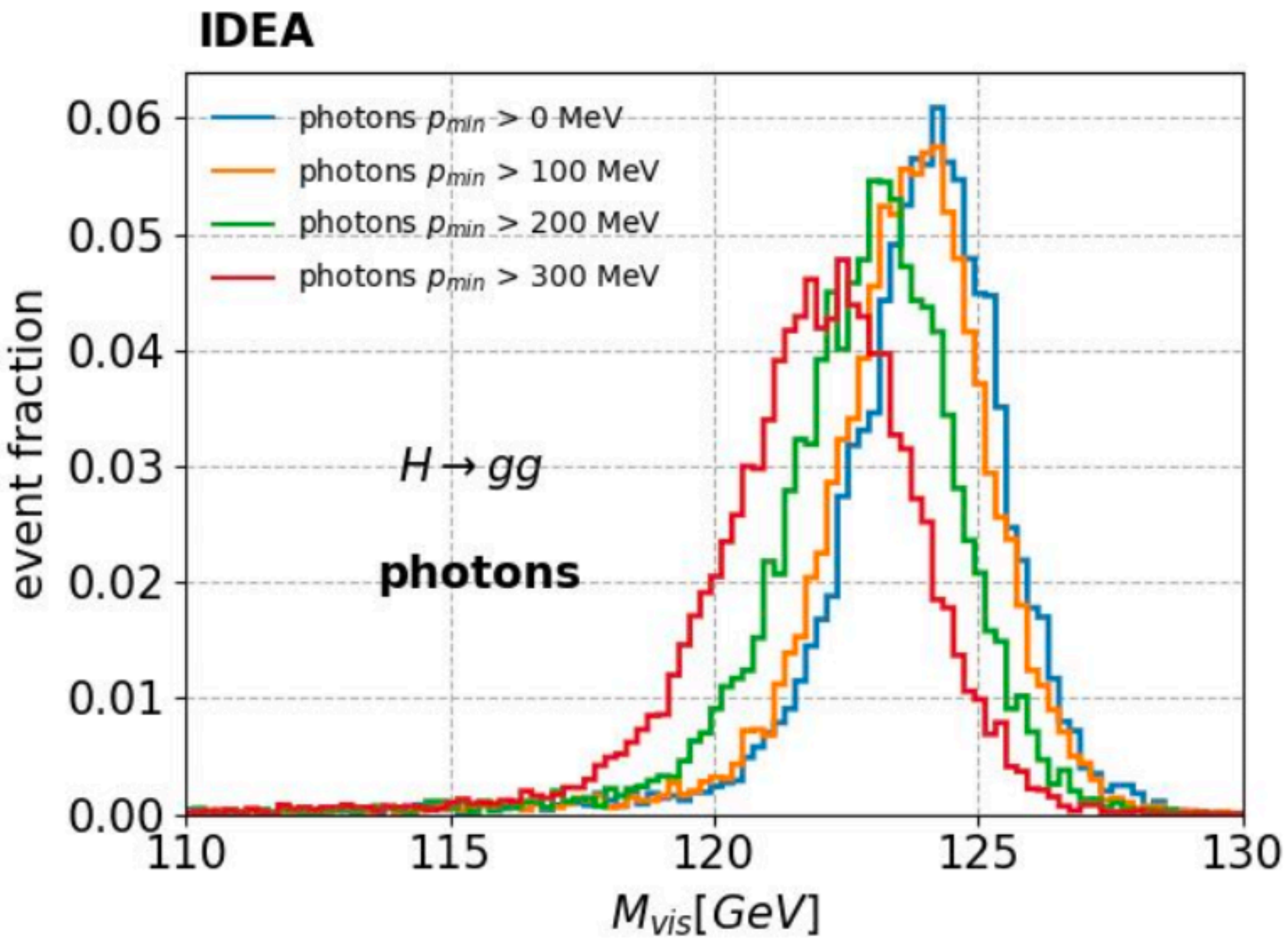
Z: $Z \to \nu_e\bar{\nu}_e(\gamma)$ radiative return

BSM: ALPS (γ's final states)

FLAVOUR: $B_s \to D_sK$, $B^0 \to \pi^0\pi^0$, $B_s \to K^*\tau\tau$, LFV $\tau \to \mu\gamma$, τ decays, τ polarisation etc.

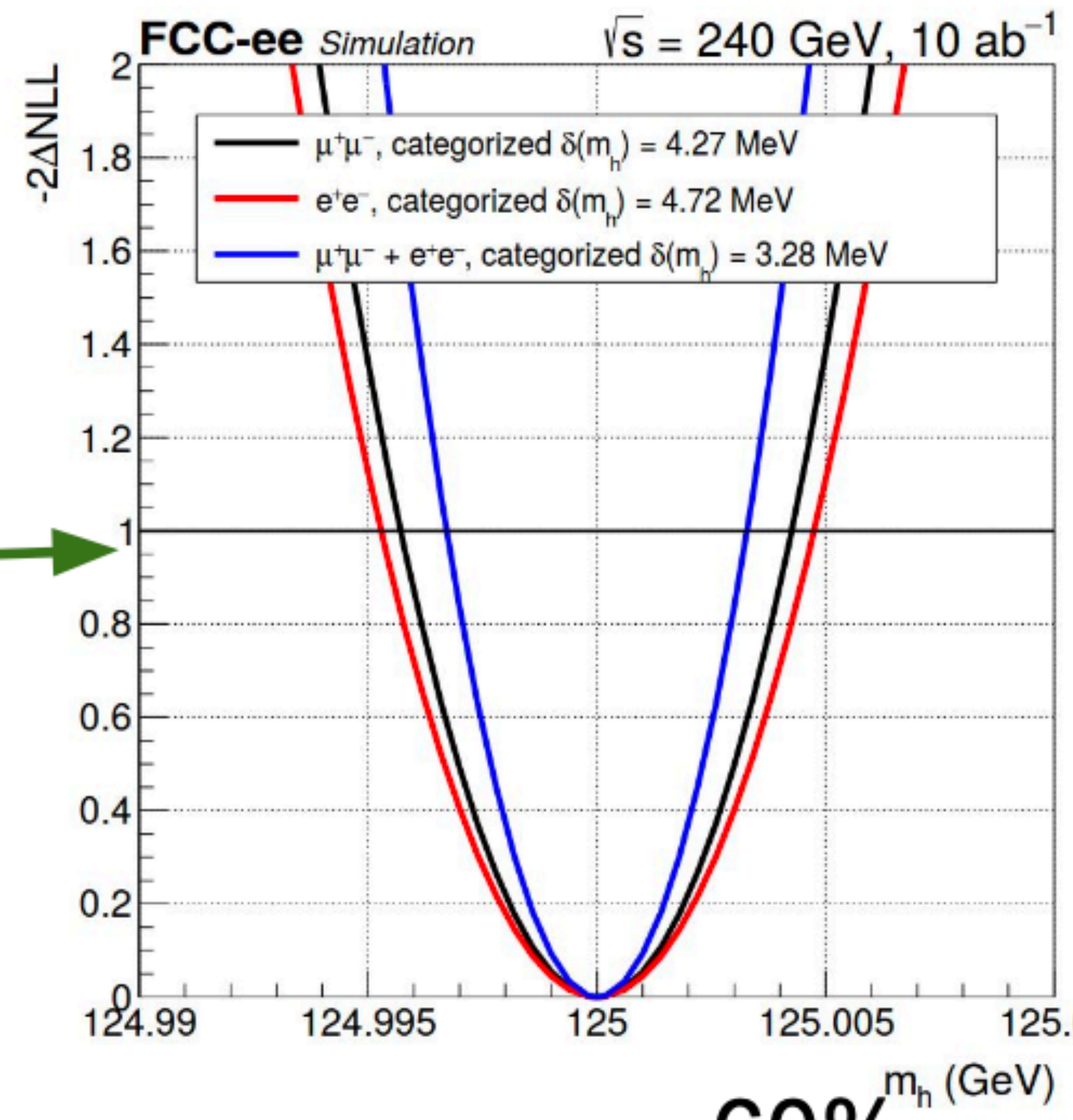
REQUIREMENTS FROM HIGGS

- Contribution to Jet resolution from low energy π^0s (e.g. $H \to gg$)



M. Selvaggi

Bremsstrahlung recovery



Z(ee) channel improves the precision on the Higgs mass.

ECAL granularity and resolution needed for efficient brem recovery → 60% improvement vs standalone tracking

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R. Aleksan et al. arxiv:2107.02002

REQUIREMENTS FROM FLAVOR: $B_s \to D_s K$

- Including the neutral decays in the reconstruction drives the ECAL resolution

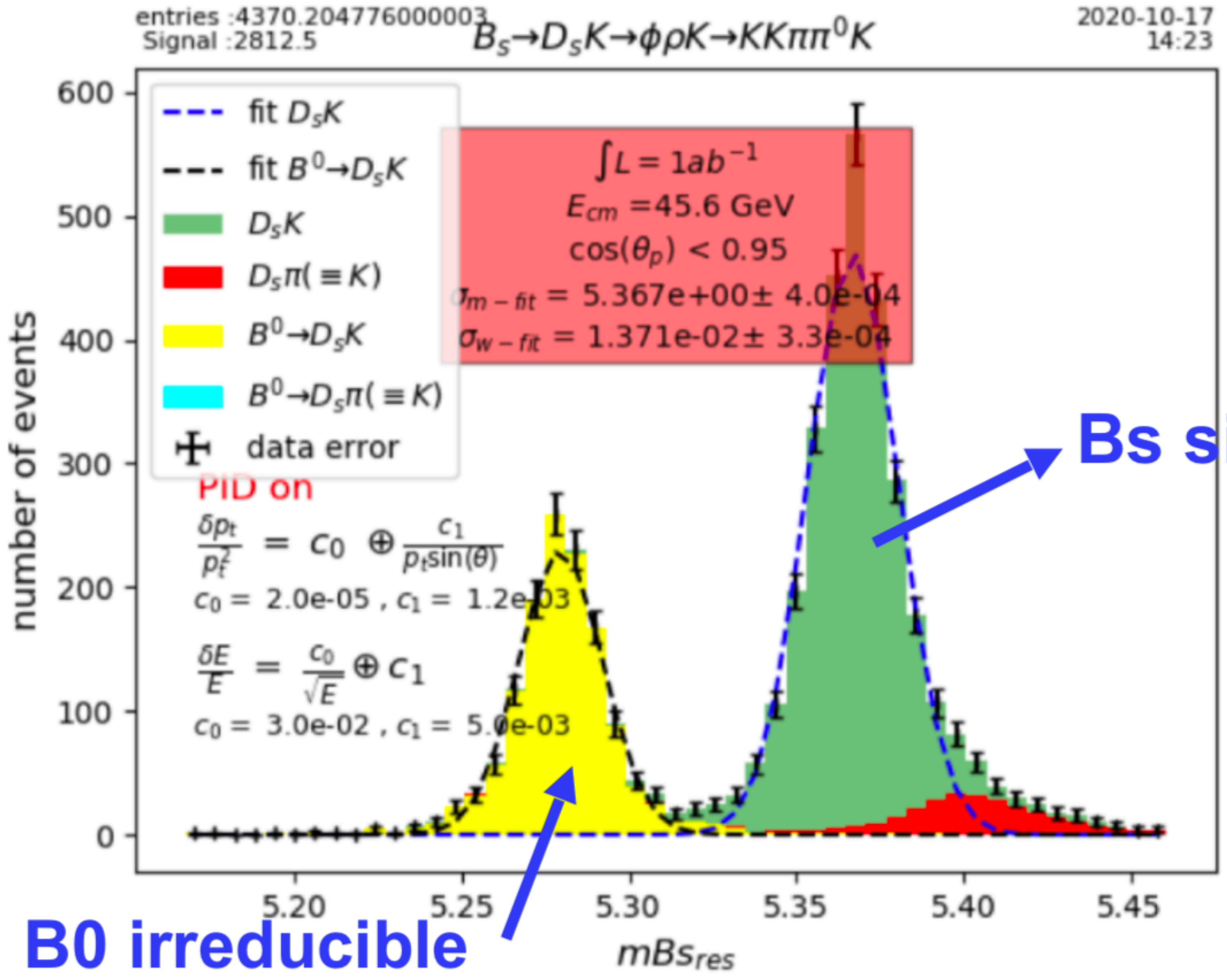
$D_s^+ K^-$	$D_s^+ \to \phi\pi$	$K^+K^-\pi^+K^-$	$\sim 5.2\ 10^5$
$D_s^+ K^-$	$D_s^+ \to \phi\rho$	$K^+K^-\pi^+K^-\pi^0$	$\sim 9.8\ 10^5$

Assuming **state-of-the-art** calorimeter with

$$\frac{\delta E}{E} = \frac{0.03}{\sqrt{E}} \oplus 0.005$$

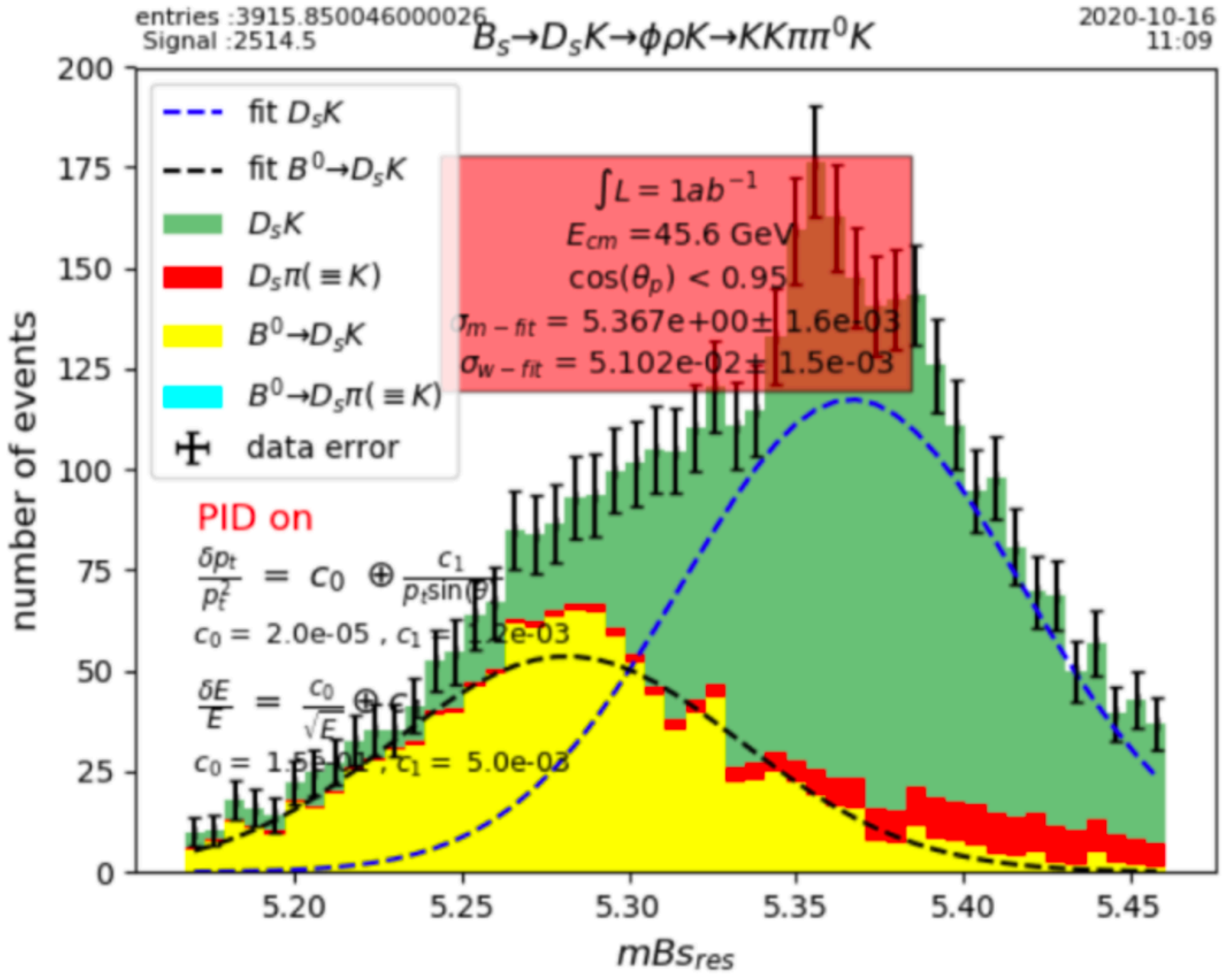
Assuming **HGCal like** calorimeter with

$$\frac{\delta E}{E} = \frac{0.15}{\sqrt{E}} \oplus 0.005$$



Bs signal

B0 irreducible bckgd



State-of-the-art Xtal-type to HGCal-type : $\sigma(D_s^\pm(\phi\rho^\pm)K^\mp) \approx 14MeV \to 51MeV$

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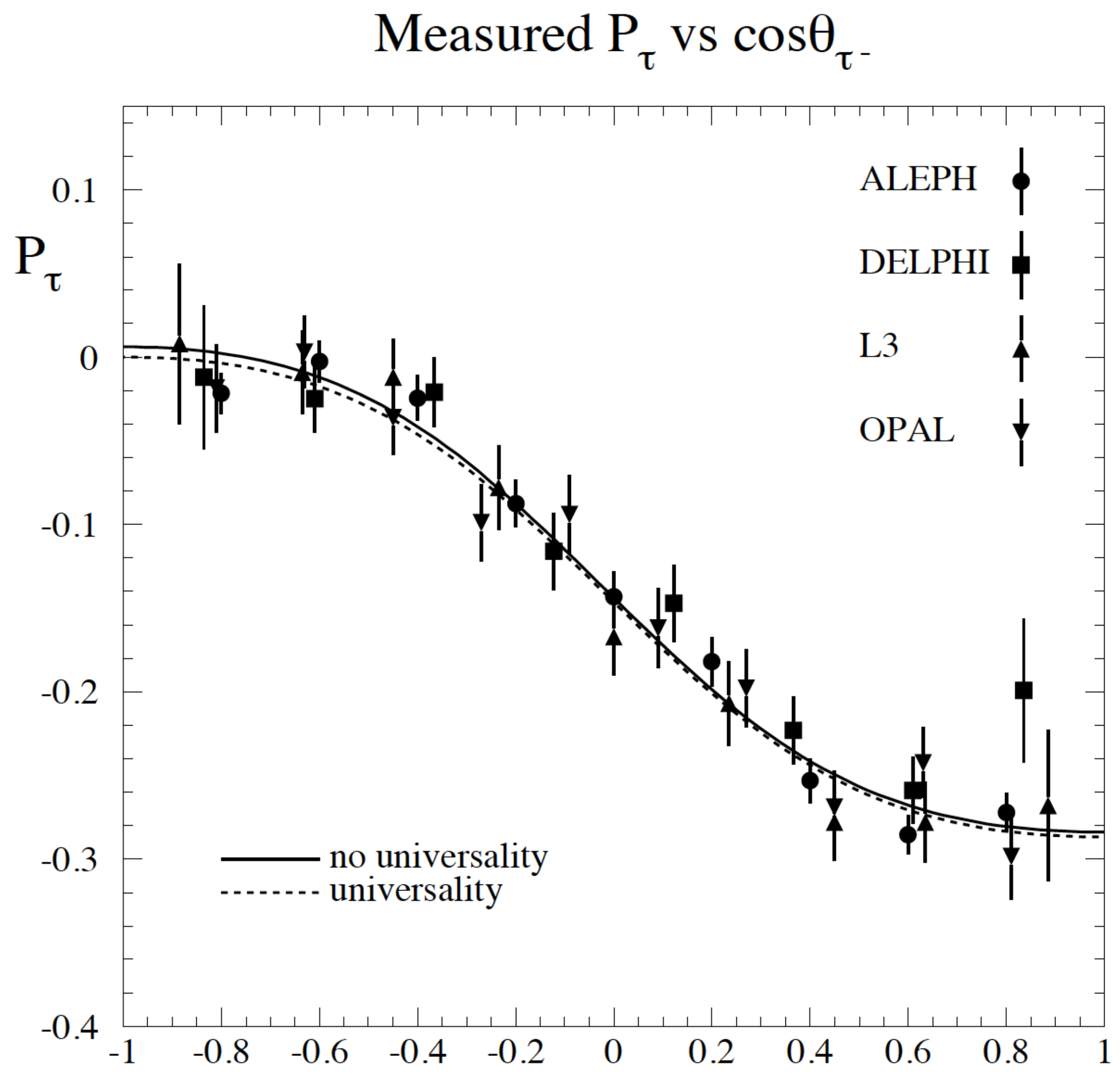
BENCHMARK GRANULARITY: TAU POLARISATION

- Tau polarisation has a central role at the FCC-ee: crucial ingredient for A_e, $sin^2\theta_{eff}$ at a circular collider
    - Desired precision of few x10^{-6} on $sin^2\theta_{eff}$, similar to that from $A_{FB}^{\mu\mu}$ but model independent
- Very large tau statistics ($\approx 1.5 \times 10^{11}$). Not only leptonic decays. Can profit of hadronic decays and choose the best channels (avoiding modelling issues).
    - For instance use best decay channels such as τ→ρντ
- Fit of $\mathscr{P}(\tau)$ vs cosθ : A_e much less affected by syst. than A_{tau}. Could achieve $\Delta(sin^2\theta_{eff}) \sim 3 \cdot 10^{-6}$

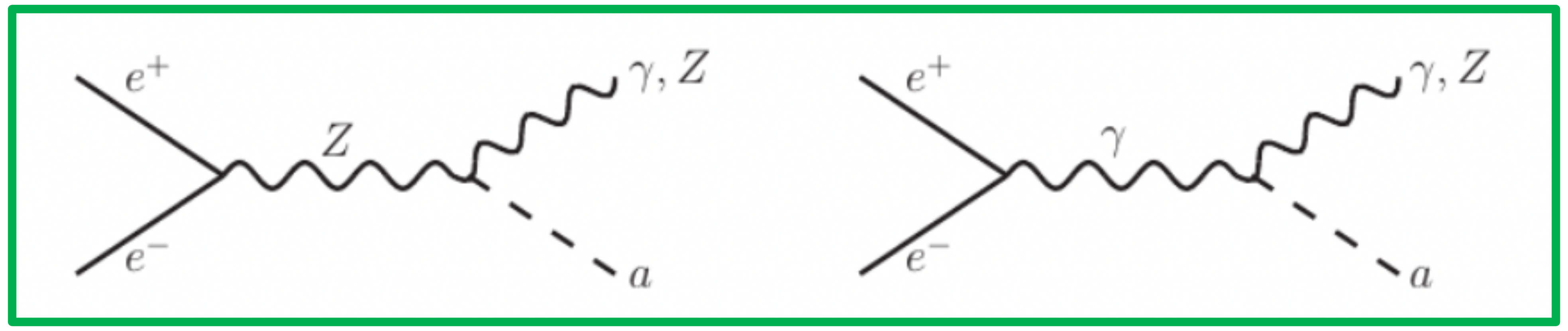
$$P_\tau(\cos\theta) = -\frac{\mathcal{A}_\tau(1+\cos^2\theta) + \mathcal{A}_e(2\cos\theta)}{(1+\cos^2\theta) + \frac{4}{3}\mathcal{A}_{fb}(2\cos\theta)}$$



Experiment	$\mathcal{A}_\tau$	$\mathcal{A}_e$
ALEPH	$0.1451 \pm 0.0052 \pm 0.0029$	$0.1504 \pm 0.0068 \pm 0.0008$
DELPHI	$0.1359 \pm 0.0079 \pm 0.0055$	$0.1382 \pm 0.0116 \pm 0.0005$
L3	$0.1476 \pm 0.0088 \pm 0.0062$	$0.1678 \pm 0.0127 \pm 0.0030$
OPAL	$0.1456 \pm 0.0076 \pm 0.0057$	$0.1454 \pm 0.0108 \pm 0.0036$
LEP	$0.1439 \pm 0.0035 \pm 0.0026$	$0.1498 \pm 0.0048 \pm 0.0009$

Crucial to have excellent $\pi^\pm/\pi^0$ separation (for the rho channel), hence ECAL granularity requirement

BENCHMARK GRANULARITY: LOW MASS ALPS

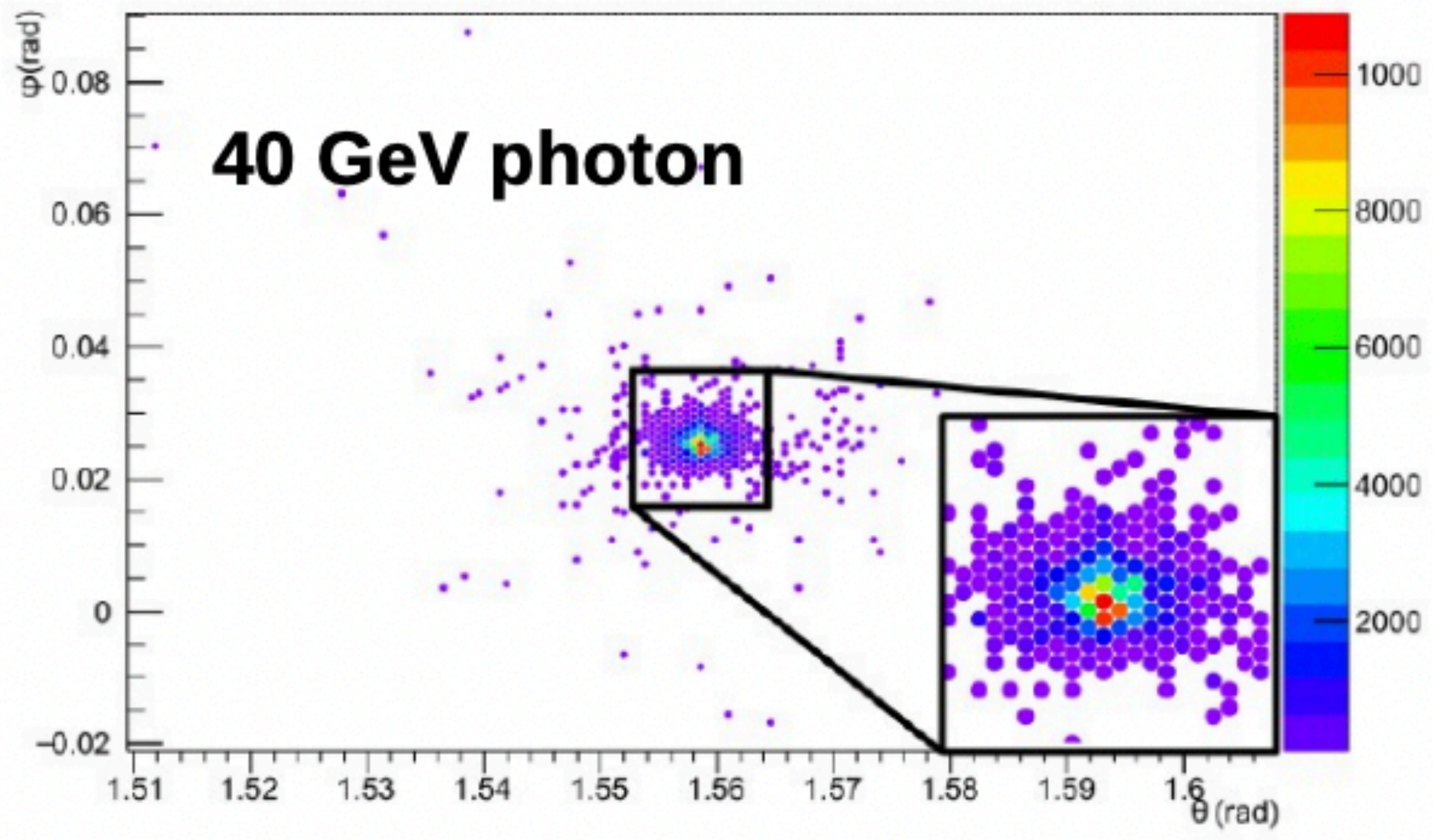


$$e^+e^- \rightarrow Z/\gamma a, a \rightarrow \gamma\gamma$$

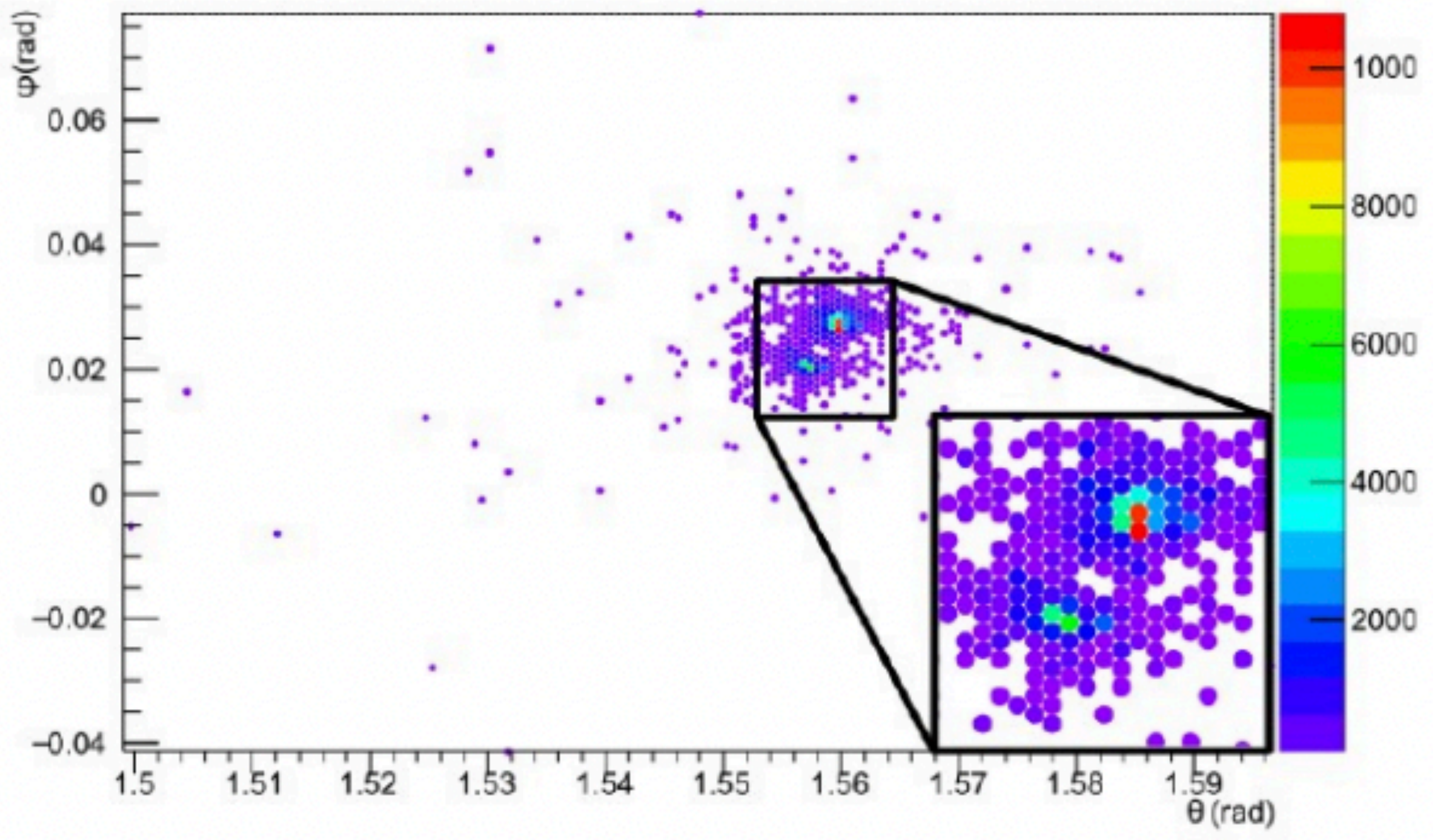
Final state with 1, 2, or 3 photons depending on energy and mass

- Associated production, ALPS mass range from ~100MeV to kinematic limit
- In the low mass range m(a)< 5GeV two very collimated photons. For m(a)=0.5 GeV the $\Delta R = 0.03$ about 7cm if the distance to the Calorimeter face is 2.5m. The size of the photon shower depends of the material and the geometry. Typically few cm.

Ph40GeV Cherenkov (Event: 1)



Pizero40GeV Cherenkov (Event: 1)



patrizia.azzi@cern.ch CERN, June 20 2023

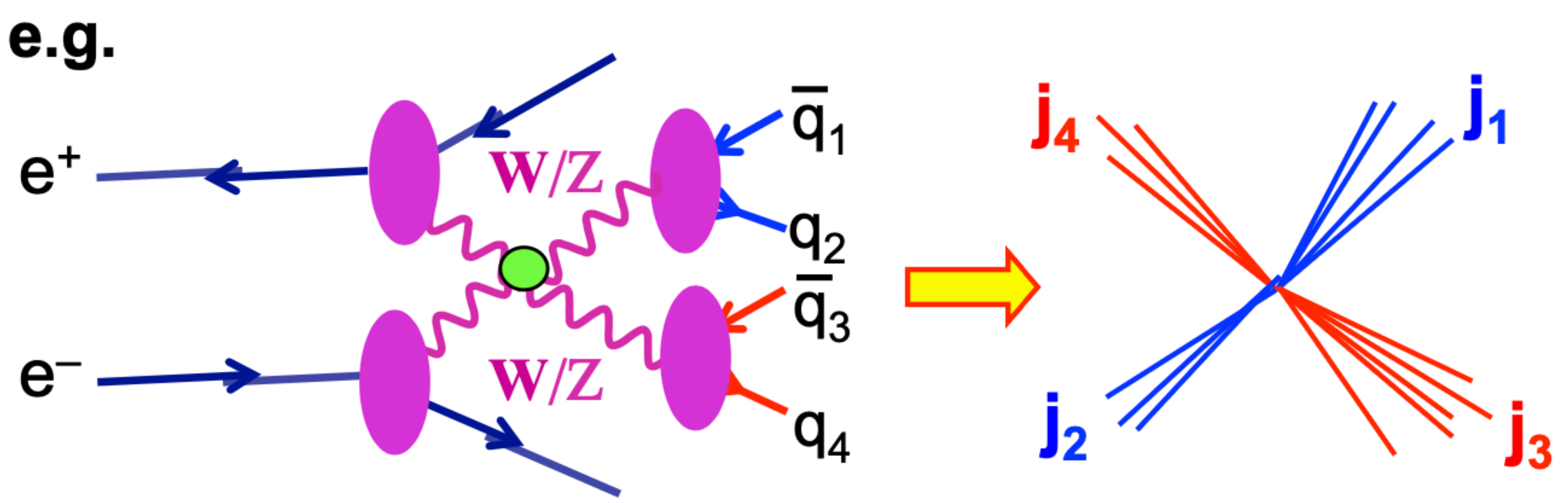
HADRONIC CALORIMETER & JETS

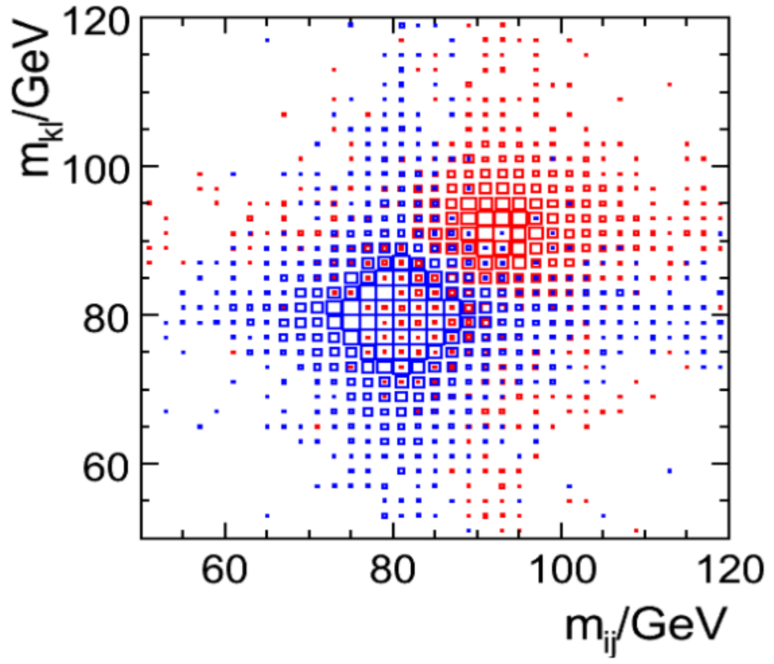
- A jet is a complex object that derives from the clustering of the products of the fragmentation process of an hadronic particle. It has charged and neutral components that leave signals in all the parts of the detector.
- Optimal reconstruction approaches, such as particle-flow, use information from all sub-detectors, beyond just the one from the calorimeter, imposing requirements on the design of the overall detector.
- Trying to disentangle:
  - detector level performances, as input to ParticleFlow algorithms
  - overall performance, as output of the complete reconstruction algorithm.

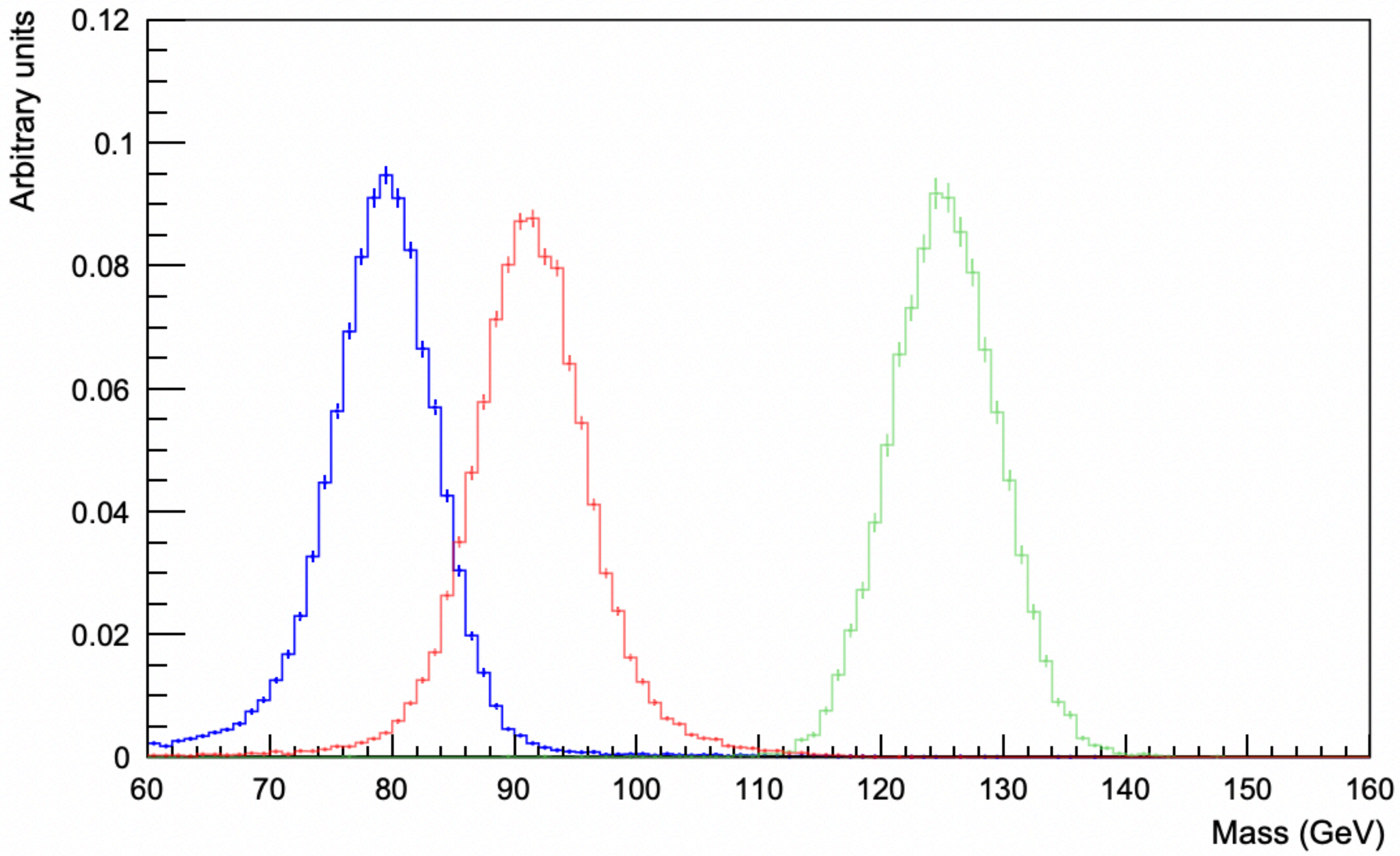
  - Advantageous to consider the performance on color singlet objects.

HADRONIC CALORIMETRY

- “Traditional argument”: separating Ws/Zs/Hs (BMR) - driver for the ~3.5% goal on the Jet Energy.
- Different physics drivers at different √s:
    - At Z/W/Higgs/top factory boson separation relevant
    - At higher energies (>1TeV) need granularity for separation of boosted objects
- Given a jet particle composition with an *ideal* ParticleFlow resolution dominated by the neutral hadron(HCAL) resolution
    - In reality granularity and thresholds matter



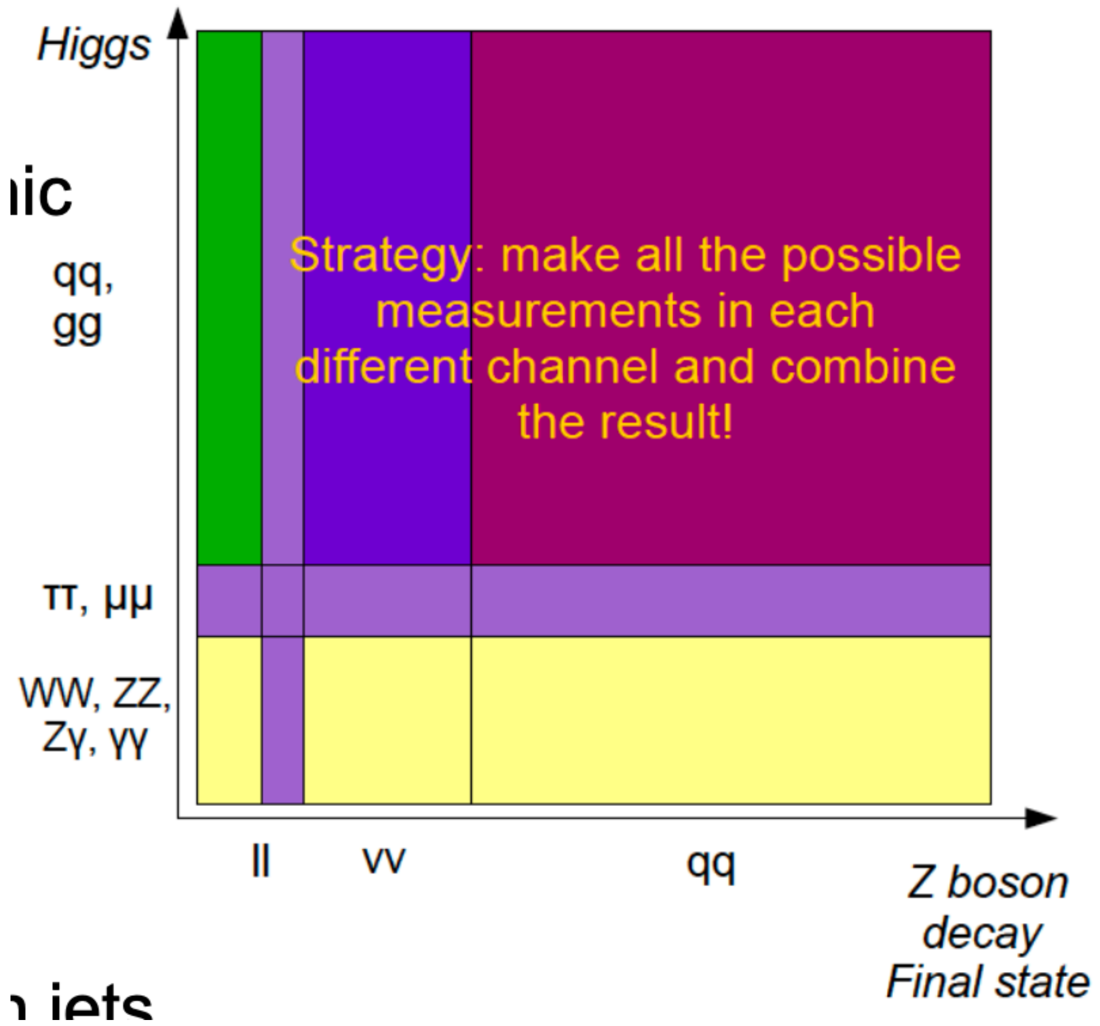




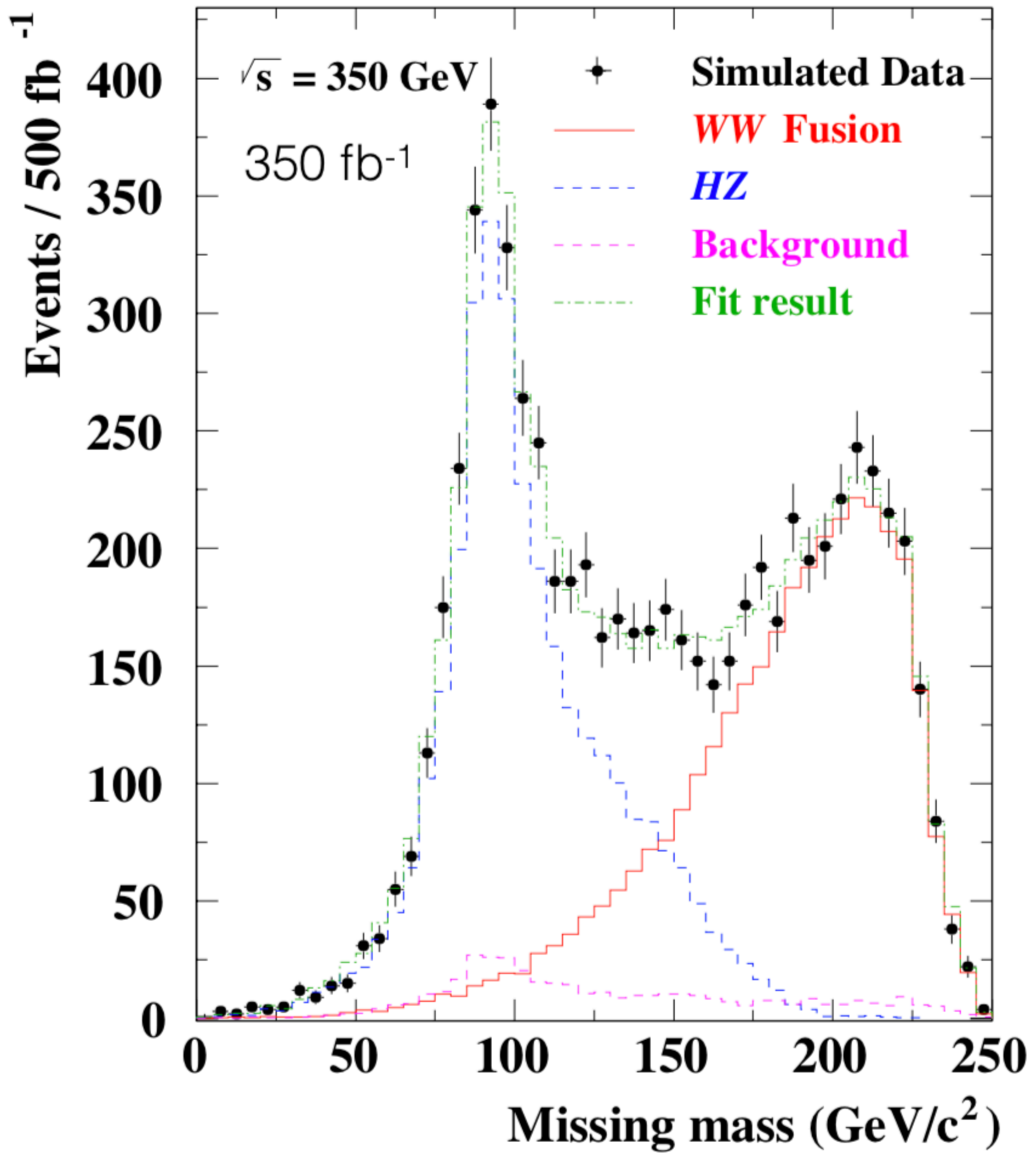
Example: DR Calo with 30%/√E. Shows BMR ~4%

BENCHMARK CHANNELS FOR HIGGS PHYSICS

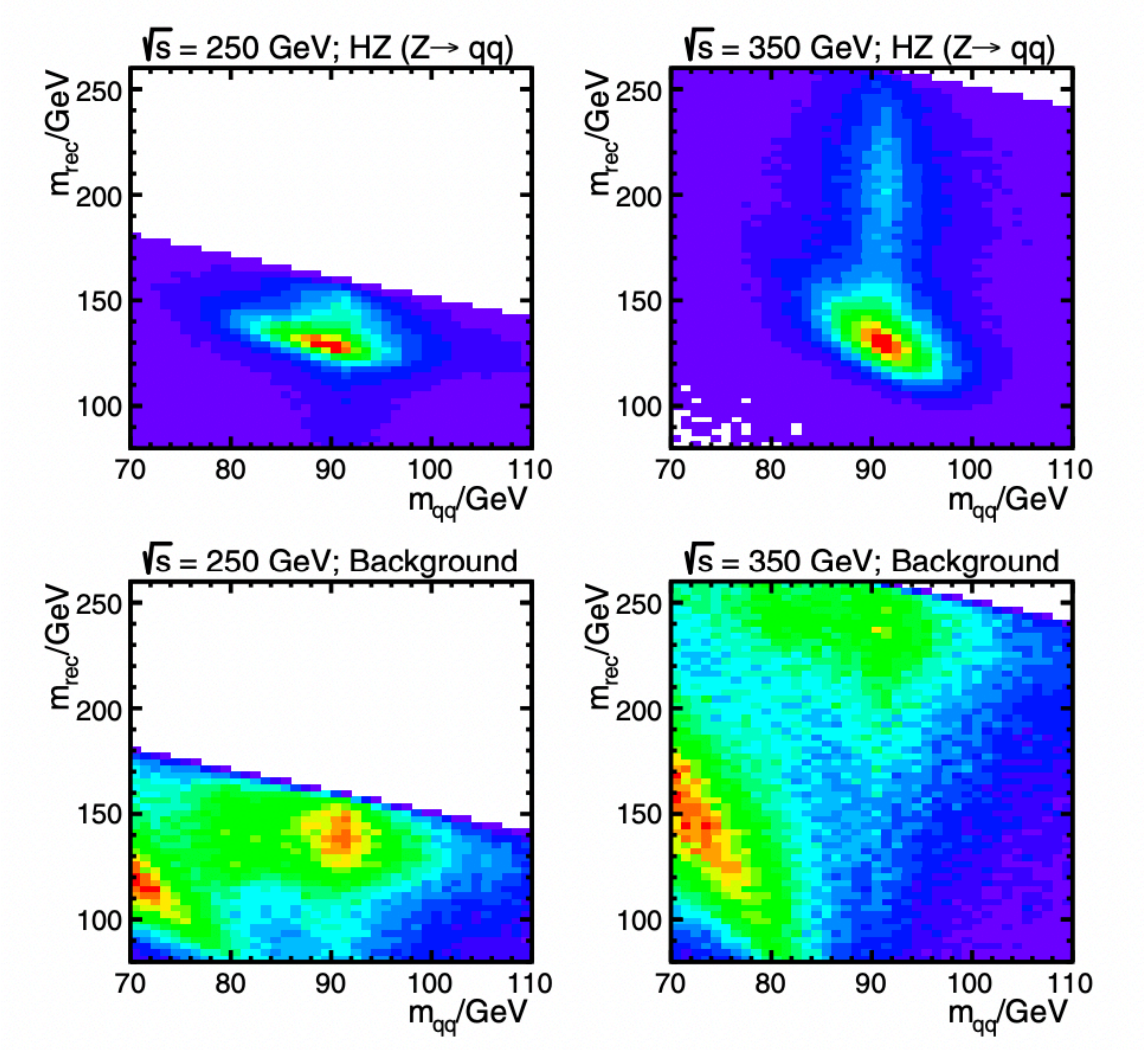
- 97% of Higgs events are hadronic or semi-leptonic
  - Identify the hadronic system in semi-leptonic events: lepton ID +missing energy
  - 4-momentum measurement of the hadronic system (color singlet)
- Event separation when more than one color singlet decays hadronically (4 jets or more): WW, ZZ, ZH
  - Identification of the color-singlet itself
- Possible benchmarks:
  - $ee \to H\nu\nu, H \to bb$ (visible energy) distinguish from background ZH->nunuH
  - $ee \to ZH, Z \to qq, H \to inv$ (visible energy)
  - $ee \to WW, ZZ, HZ \to full - had$ (need jet reco)
- NB if 4 jets events and close event kinematic, angular resolution more relevant than energy



Strategy: make all the possible measurements in each different channel and combine the result!



BENCHMARK RESOLUTION: HIGGS RECOIL WITH Z->qq



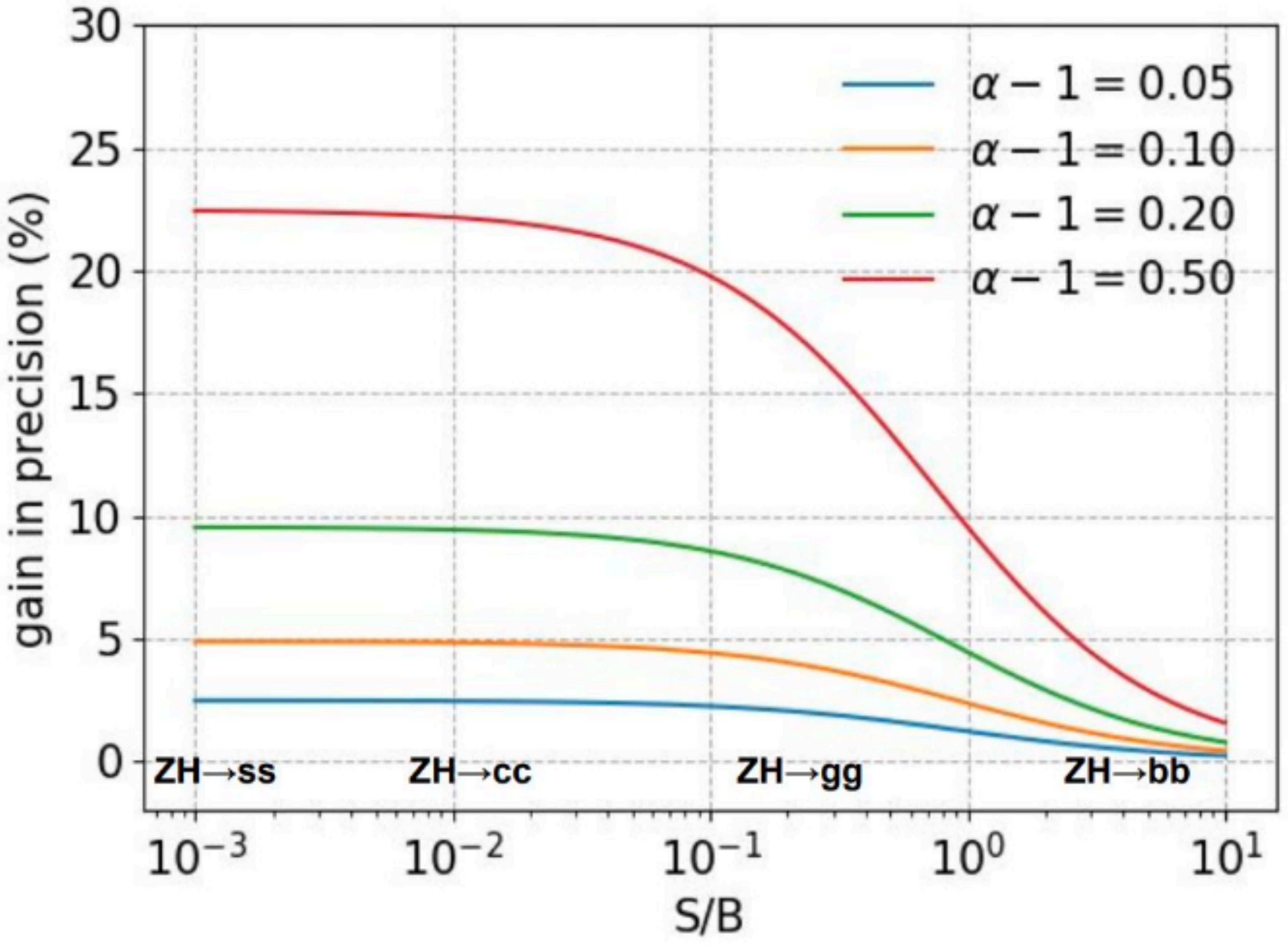
- Hadronic Z events increase the statistics of the recoil analysis by O(10)
- Improvement on ZH cross section of 20% only…
  - Need to limit background improving accuracy on the recoil mass reconstruction
- In a CLIC study with optimised selection, a factor of 2.3 improvement on the ZH cross section can be achieved (especially at √s=350 GeV)

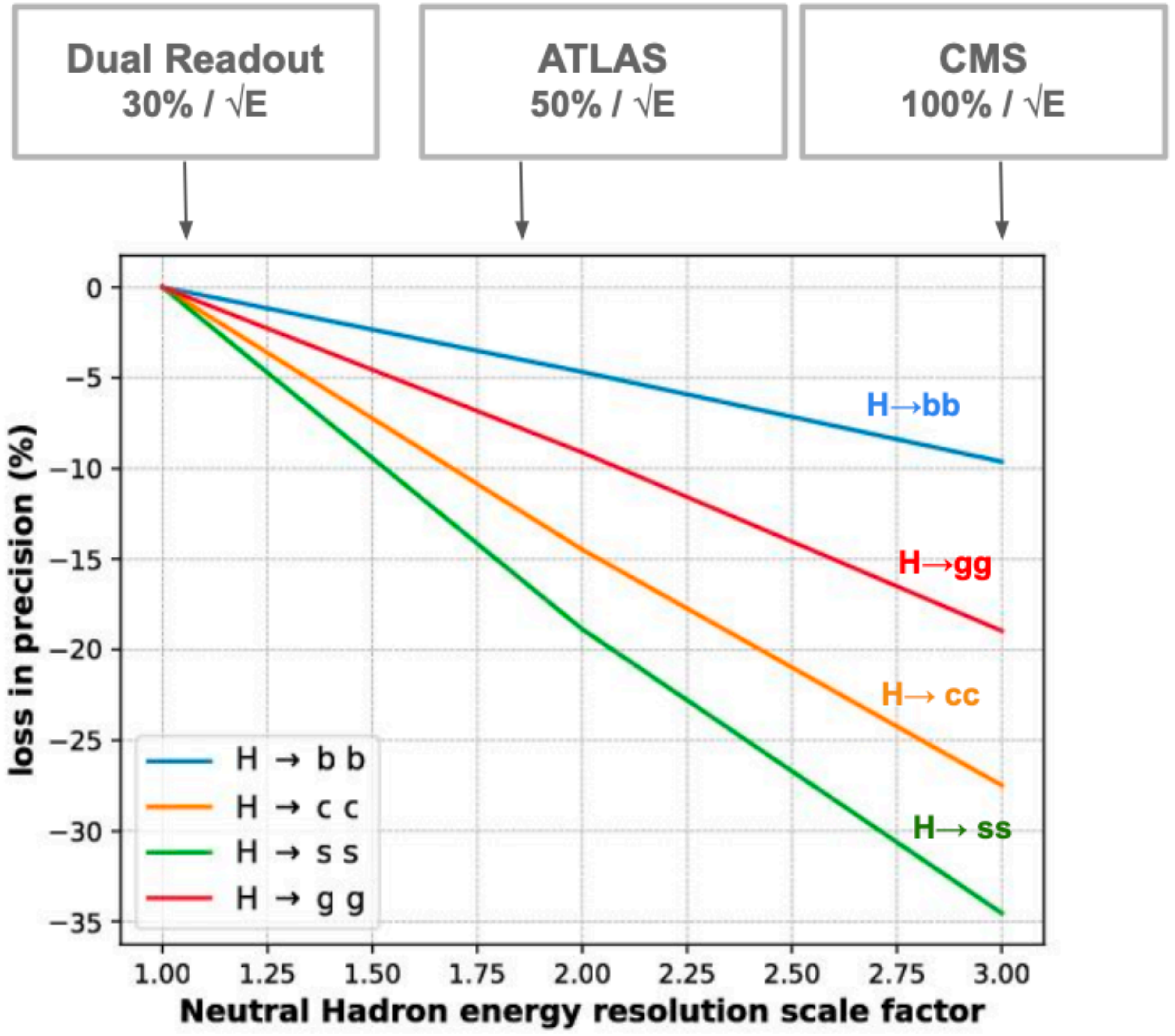
https://link.springer.com/article/10.1140/epjc/s10052-016-3911-5

REQUIREMENTS FROM HIGGS HADRONIC FINAL STATES

Largest gain from JER expected for S/B << 1:

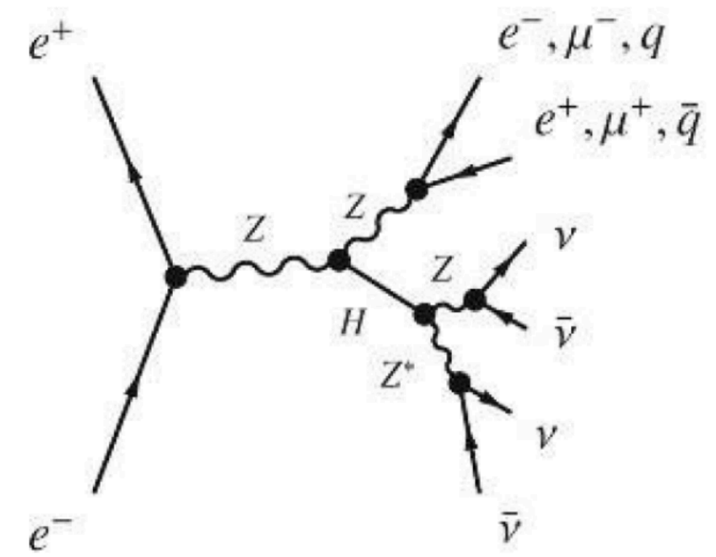
If relative improvement **α**, expect √**α** increase in precision





Observe less degradation than expected, studies will have to be repeated with full simulation

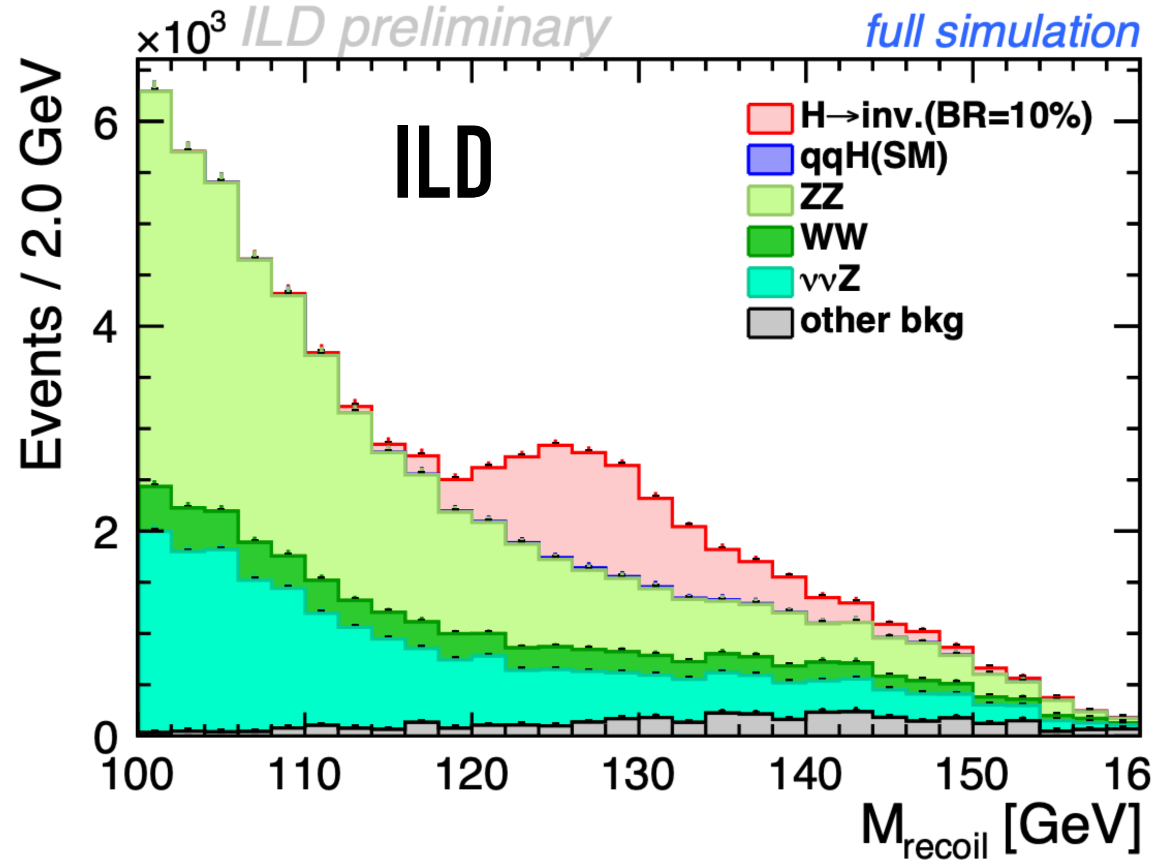
M. Selvaggi FCC Week 2023

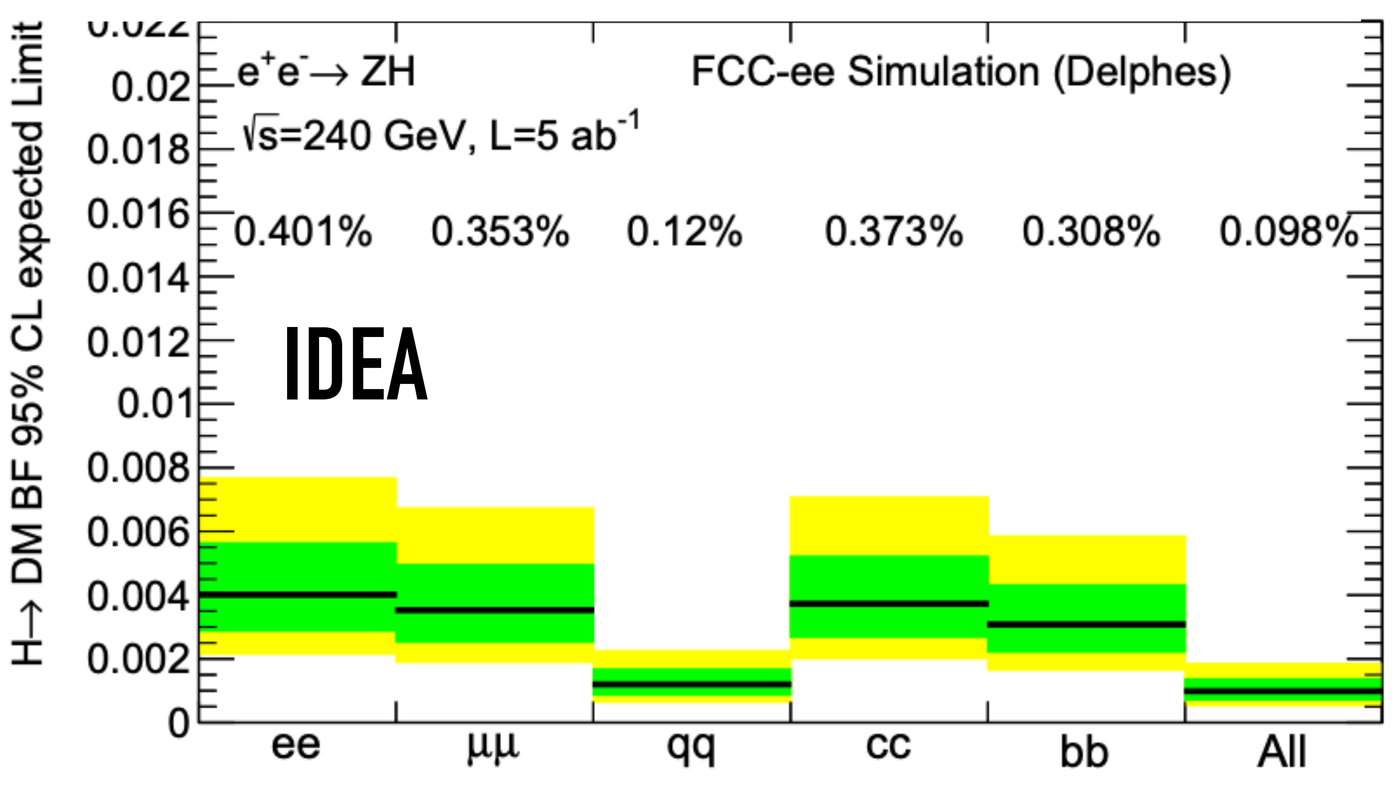


REQUIREMENTS FROM HIGGS->INVISIBLE

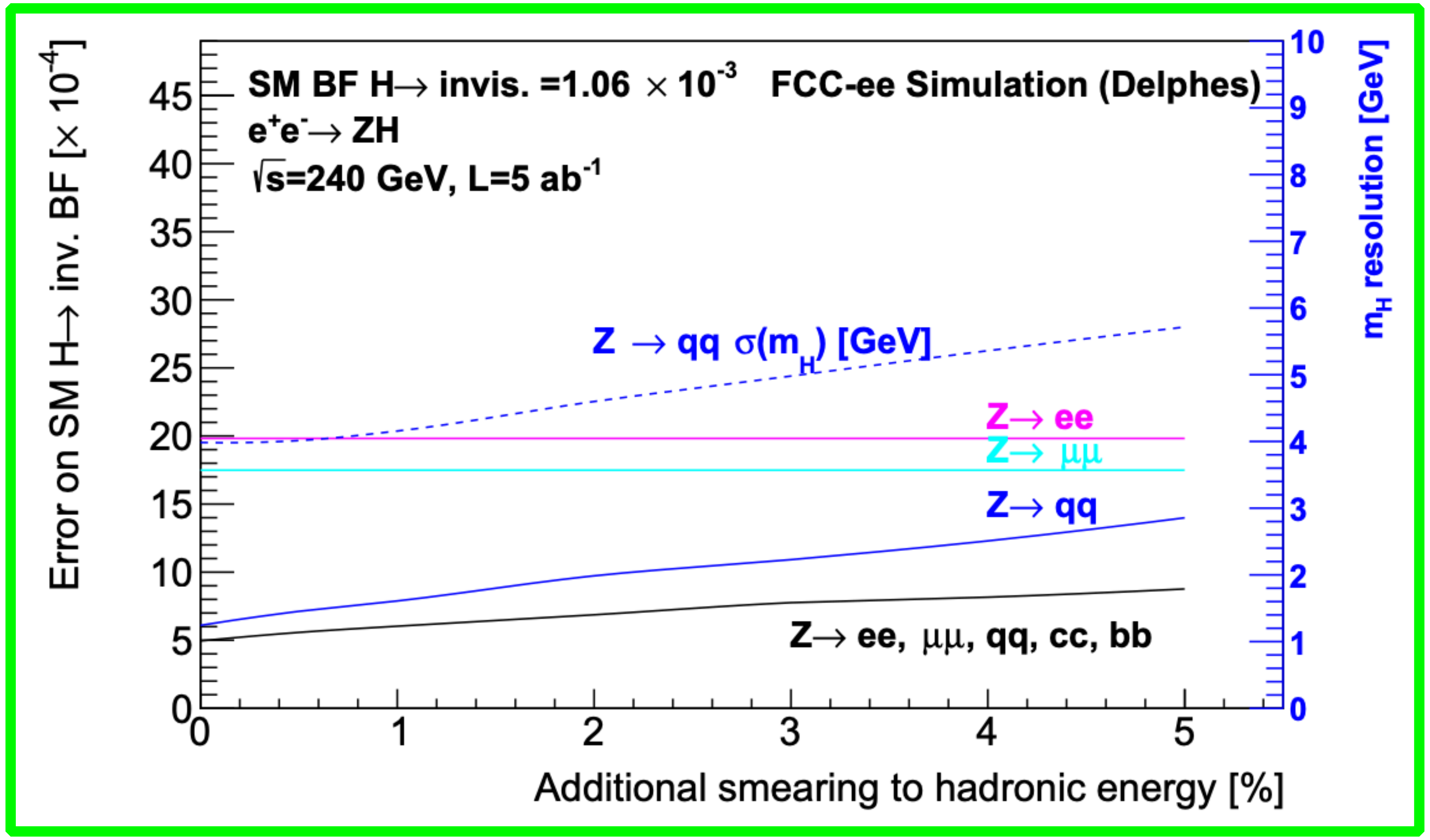
- $H \rightarrow inv.$ in the recoil method at 240/250GeV is a golden channel for DM search.
- Preliminary studies from ILD and FCC-ee (different conditions aside) show a sensitivity to BSM with BF>0.2%. 10 times better then the expected HL-LHC

https://pos.sissa.it/364/358/pdf





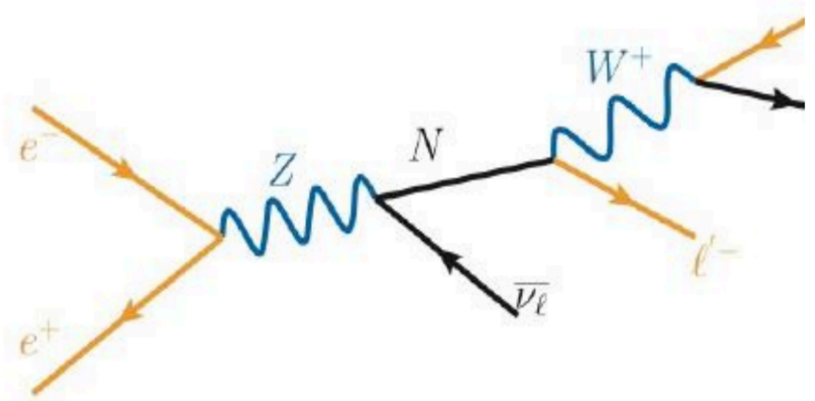
Metha,Rompotis

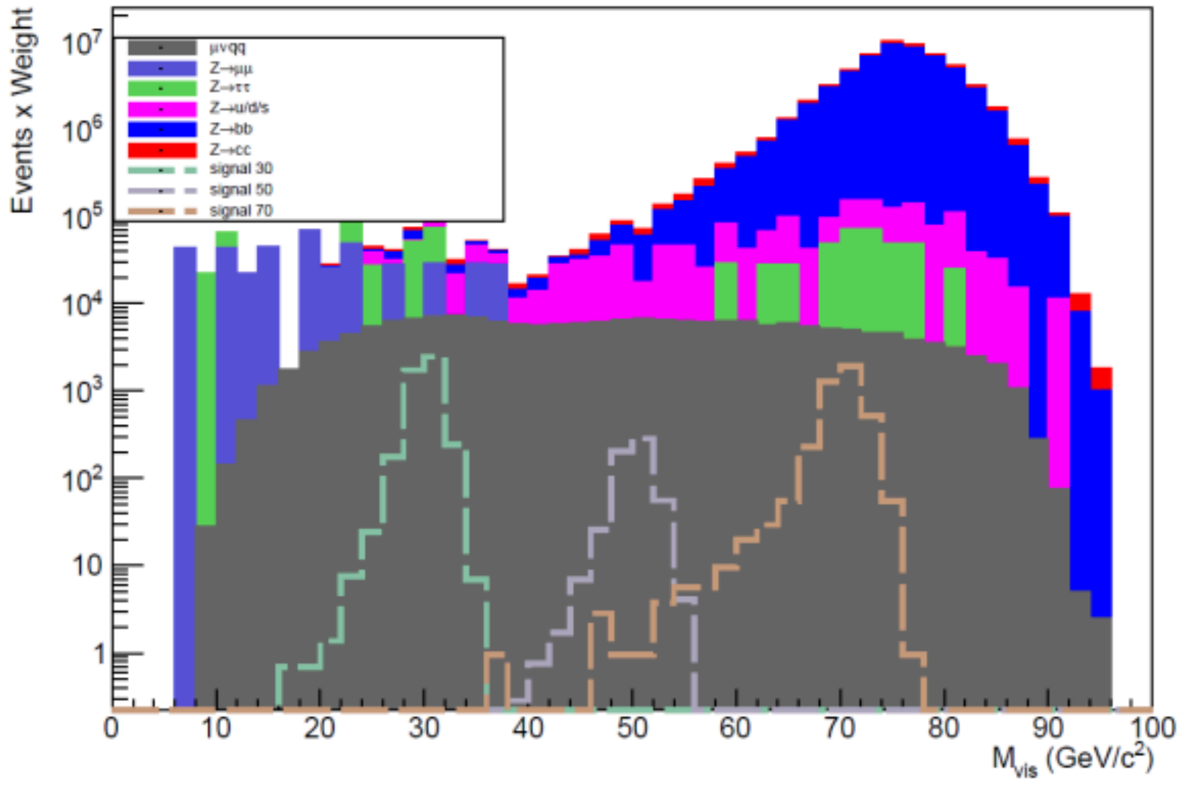


Add an extra Gaussian smearing to hadronic channels.

Results in 130% increase in error for qq channel and 80% in the combined for a 5% additional smearing

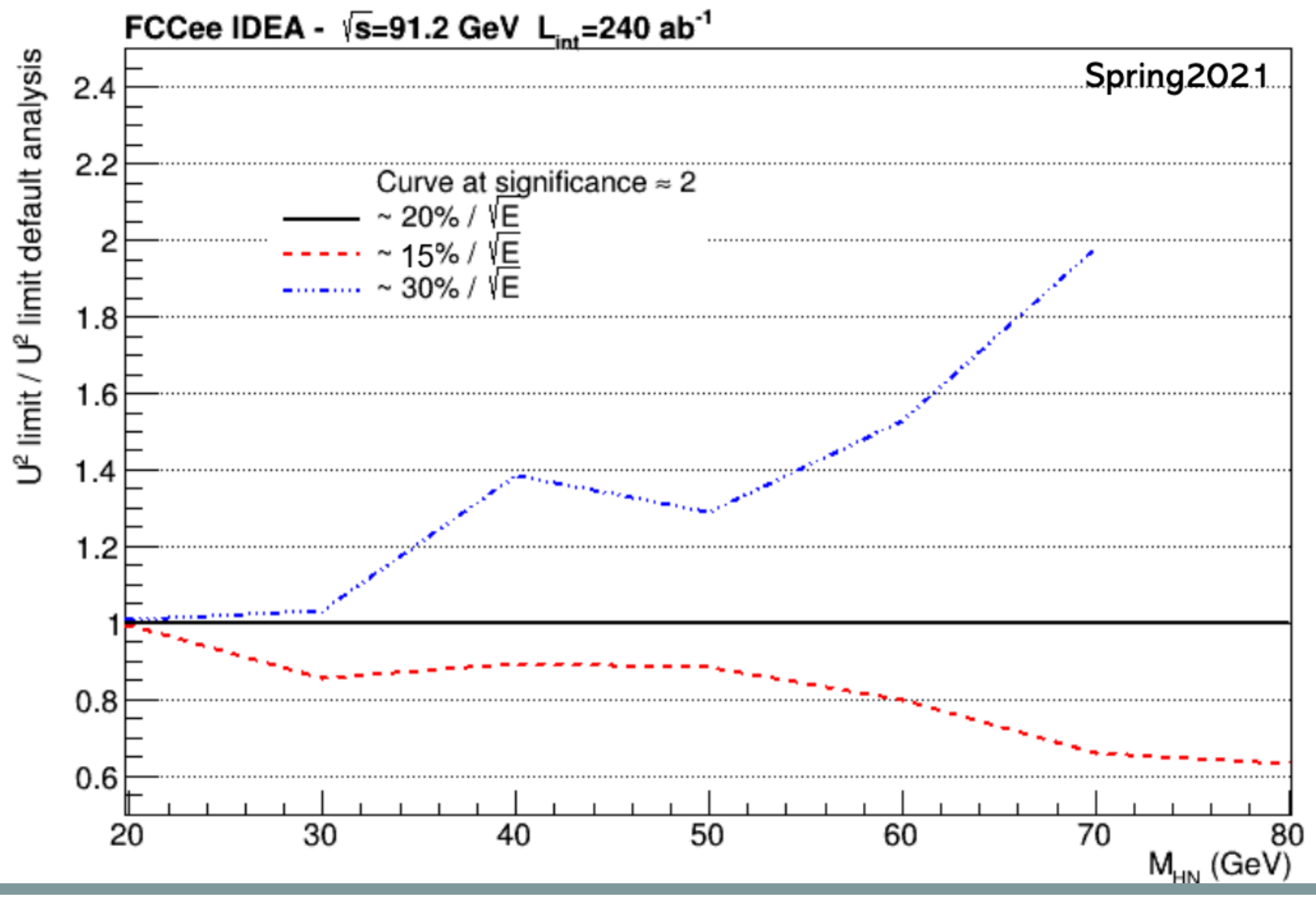
REQUIREMENTS FROM BSM





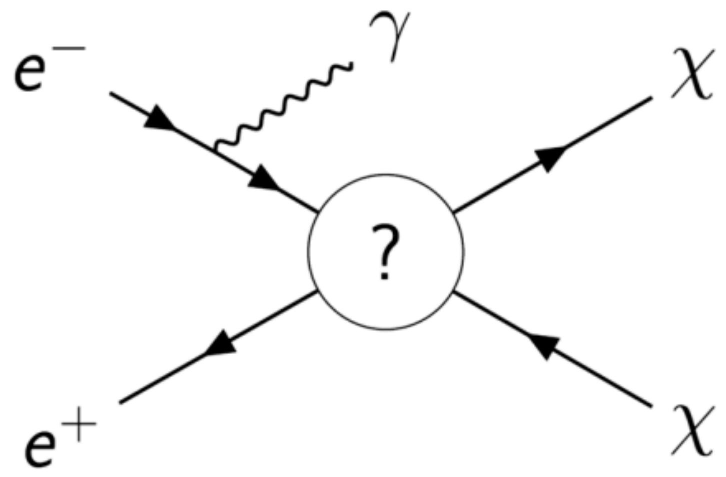
EFFECT OF ENERGY RESOLUTION

- Prompt $HNL \rightarrow \mu q \bar{q}'$ process
- Variation of background when varying mass window as a function of $\sigma(M_{jj})$

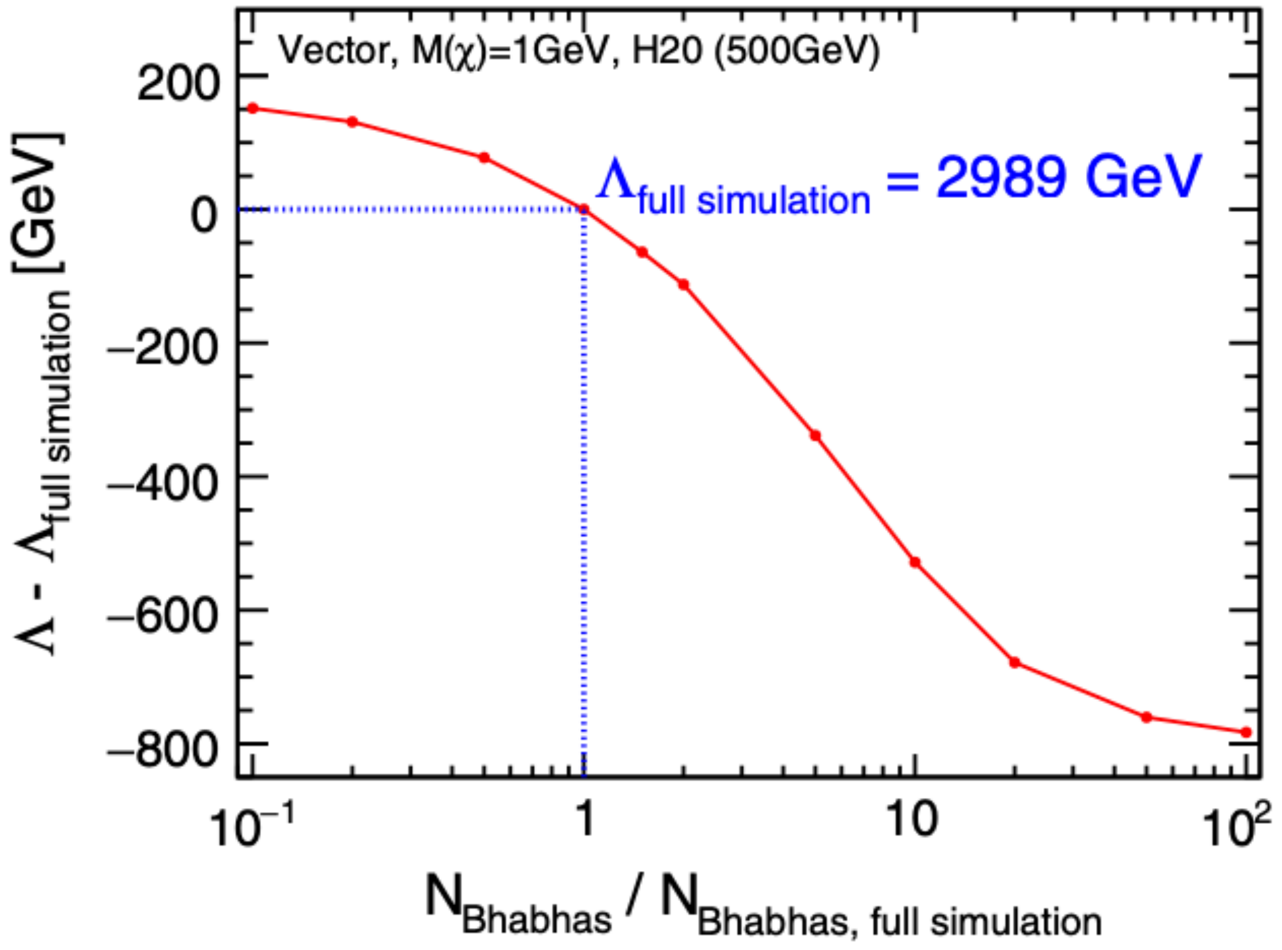


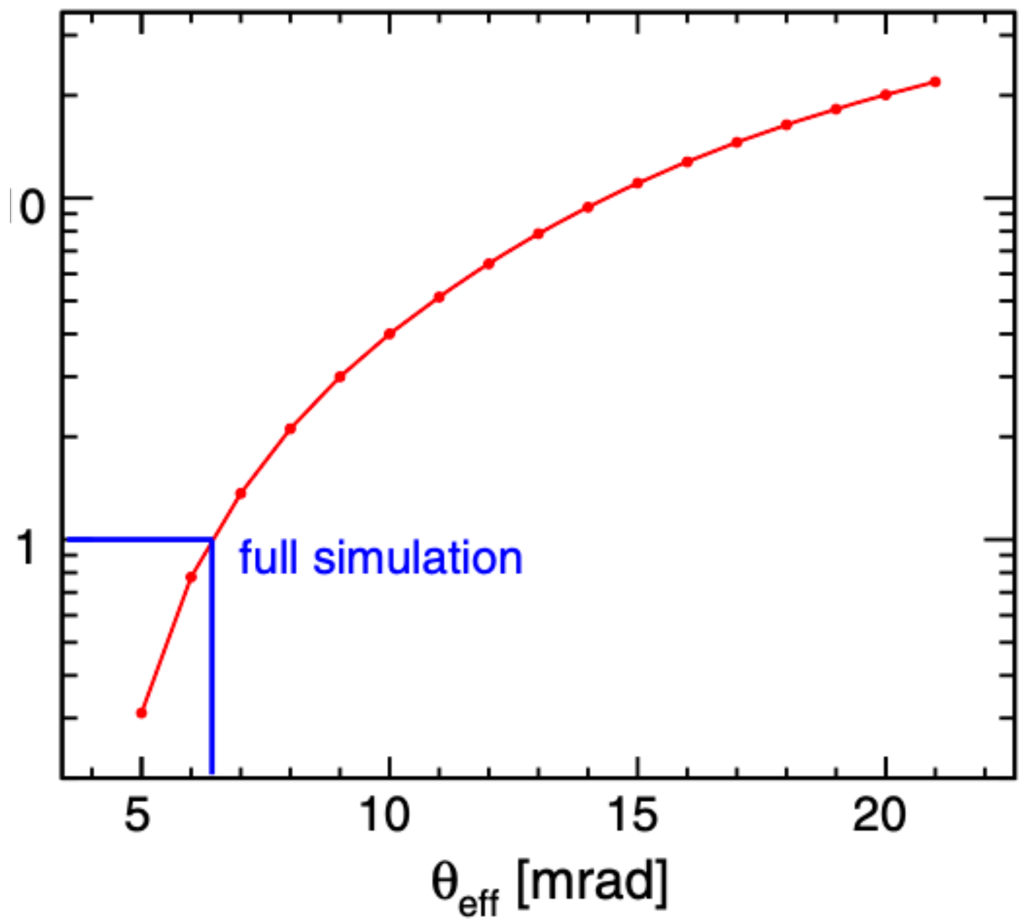
EFFECT OF HERMETICITY

PhysRevD.101.075053



- Study variation of background to mono-photon WIMP search from Bahba as function of max polar angle
- Decreasing the acceptance for electrons from $\theta_{eff} = 7^o$ to $\theta_{eff} = 20^o$ the sensitivity to Λ_{95} reduces by 700GeV





Acceptance

SUMMARY & CONCLUSIONS

- The physics program of future EWK/Higgs/Top factories is extensive and extremely ambitious.
- The design of the detector**s** will have to match the physics needs. We are exploring the most challenging benchmarks, not just the flagship measurements
  - *strictest requirements from the Z pole run more than Higgs factory mode*
- New software and analysis tools along with new detector technologies will allow us to tackle ambitious goals of improve efficiencies and minimise the systematic uncertainties.
  - We discover we have access to measurements we did not think of before
- **Pushing the limits is an exercise in physics and the breeding ground for brand and bold new ideas in all aspects. Be part of this exciting times.**

SECOND • ECFA • WORKSHOP

on e^+e^- Higgs / Electroweak / Top Factories

11-13 October 2023
Paestum / Salerno / Italy

Topics:

- Physics potential of future Higgs and electroweak/top factories
- Required precision (experimental and theoretical)
- EFT (global) interpretation of Higgs factory measurements
- Reconstruction and simulation
- Software
- Detector R&D

Registrations open!!! https://agenda.infn.it/event/34841/

BACKUP

BENCHMARK INPUT TO PARTICLE FLOW

- In events with many jets such as $ZH \rightarrow 6jets$ the combinatoric and correct assignment are strongly influenced by the energy resolution
- Here impact of correct association of photons to jets, which affects the overall jet resolution

https://doi.org/10.1088/1 748-0221/15/11/P11005

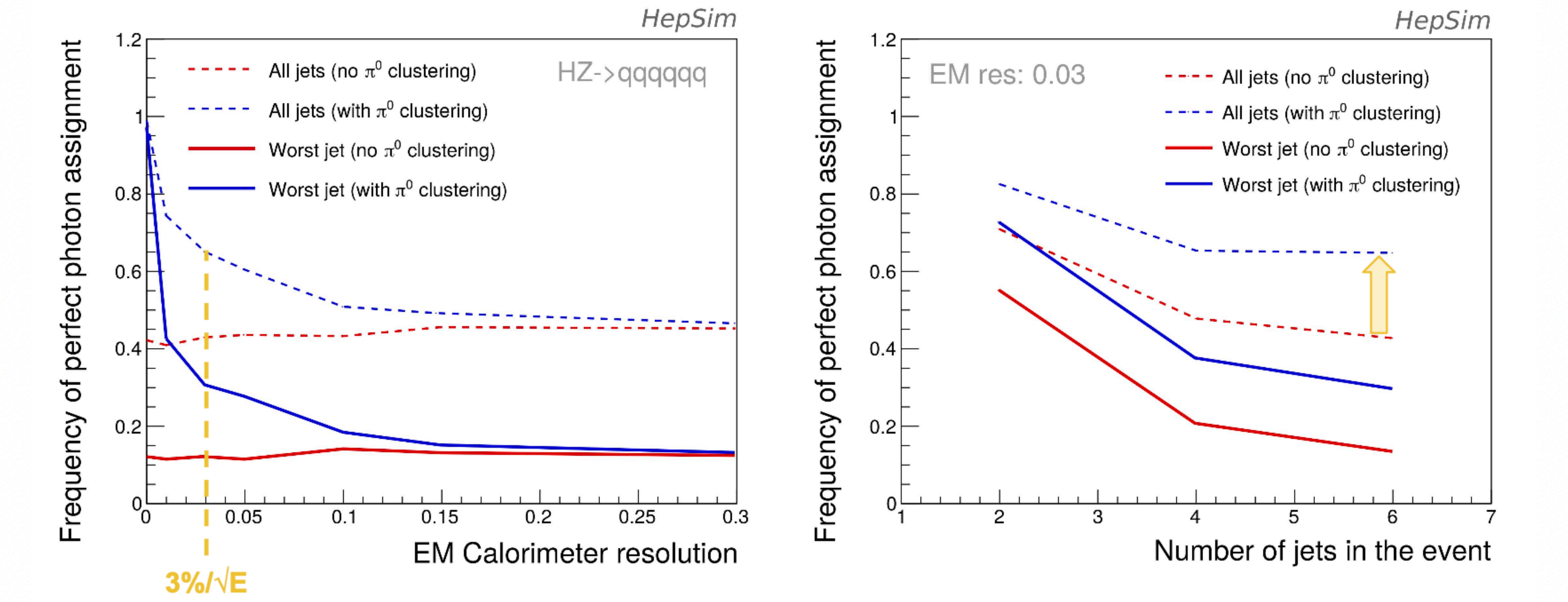
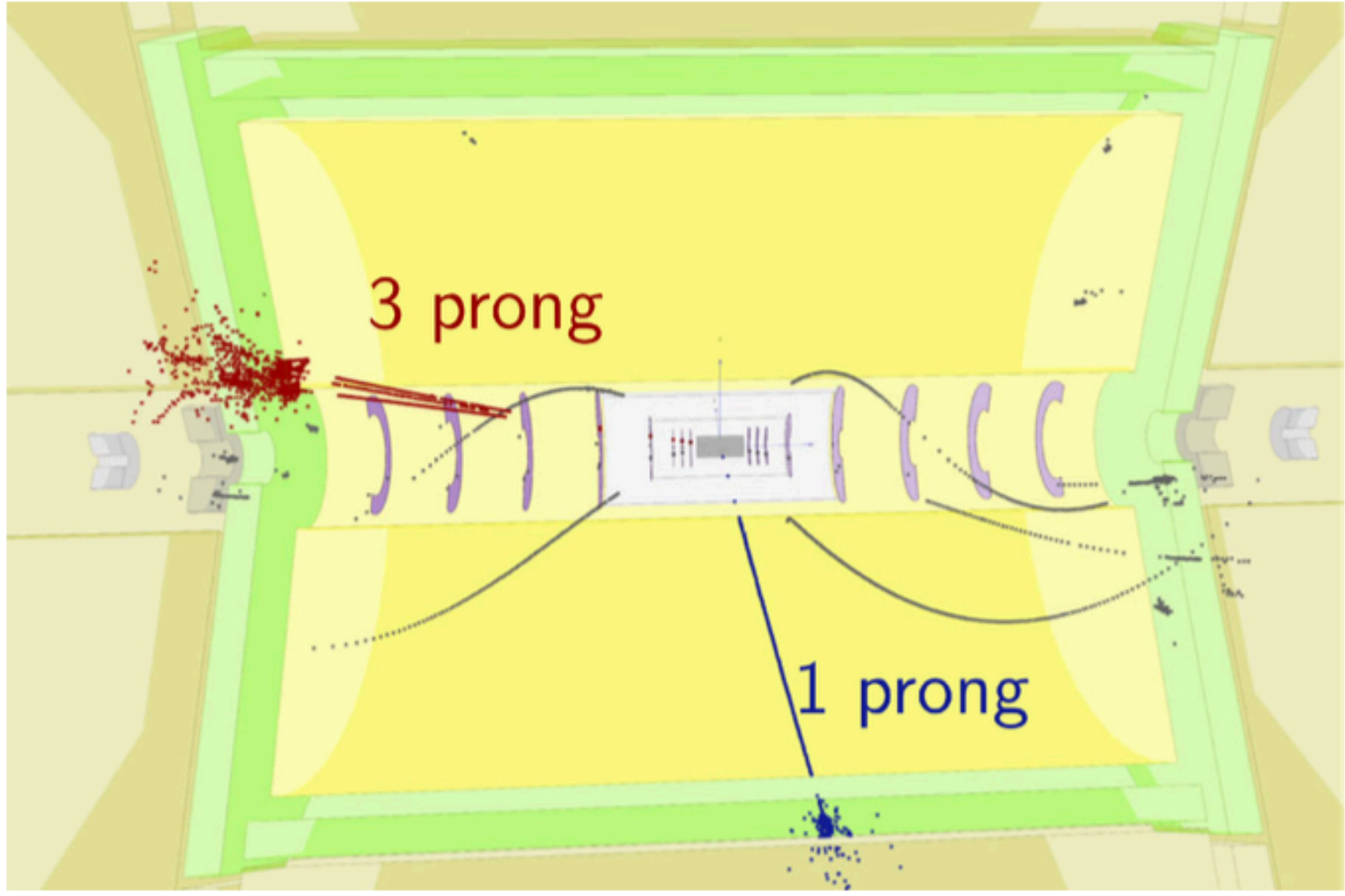


Figure 11. Frequency of events where photons are perfectly assigned to the corresponding jet as a function of the number of jets in the event, assuming a calorimeter resolution of $3\%/\sqrt{E}$ (left), and as a function of calorimeter EM resolution in the case of the $HZ \rightarrow q\bar{q}q\bar{q}q\bar{q}$ sample (right).

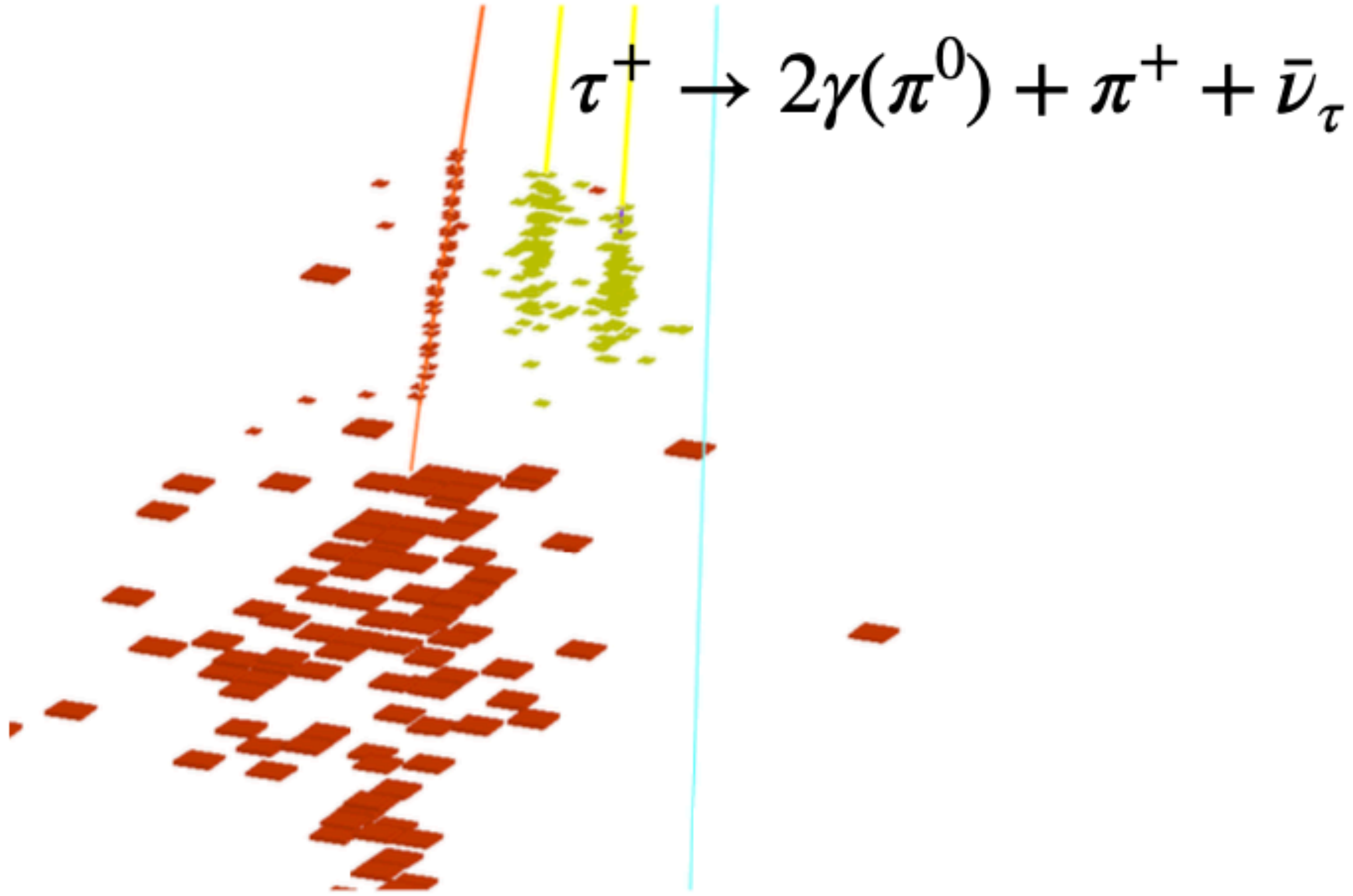
REQUIREMENTS FROM HIGH ENERGY TAUS

- High-energy τ's: From heavy boson decays: Z, H, (W)

Typical signature:
Low-multiplicity jet: charged pions,
photons (from π⁰)



CLIC 1.4 TeV Hνν, H-> ττ



Key calorimeter features: (lateral) granularity, em energy resolution

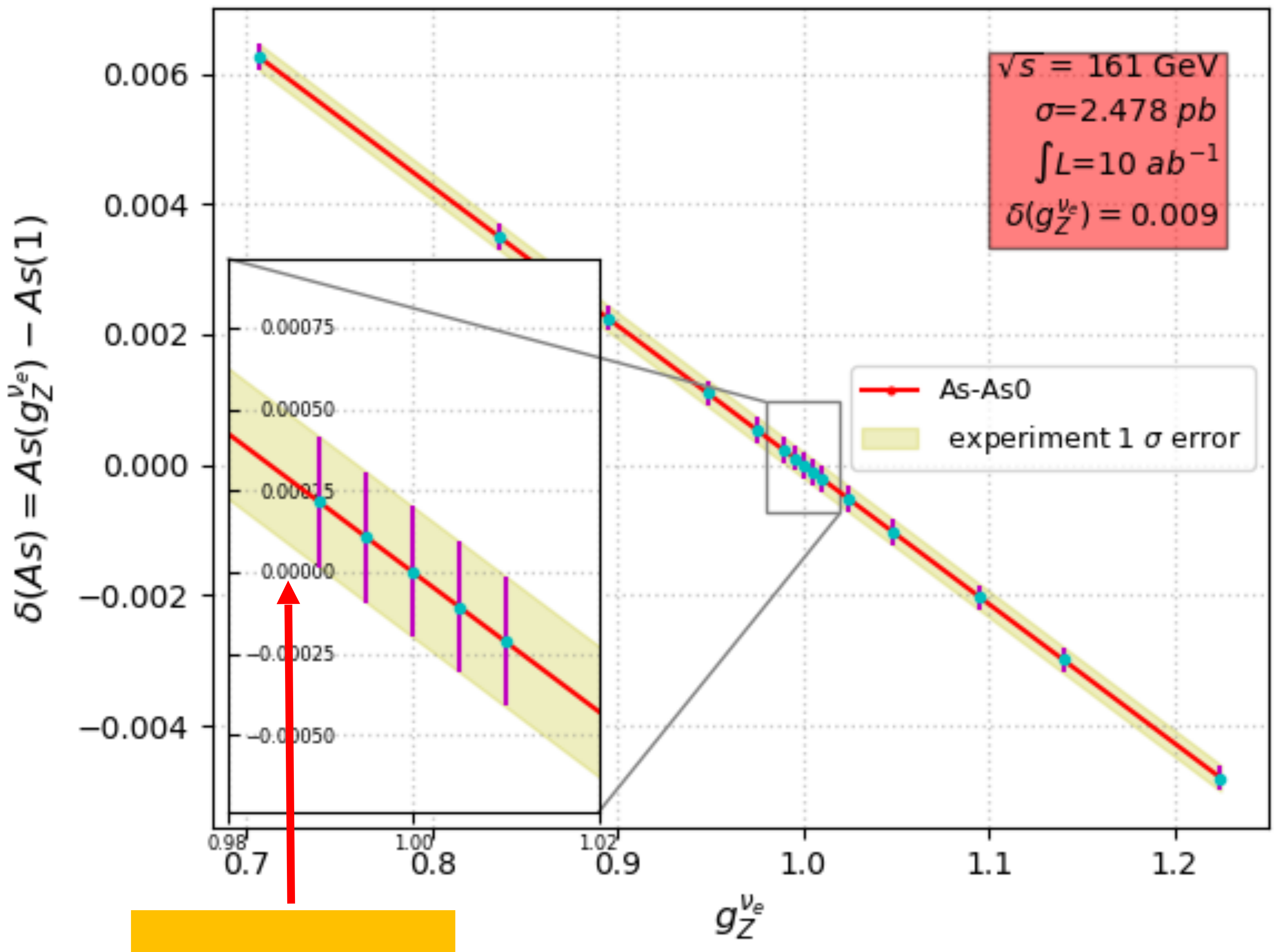
F. Simon - ECFA Calorimeter WS 2023

BENCHMARK ECAL ENERGY RESOLUTION: $Z \rightarrow \nu_e \nu_e \gamma$

- Measurement of the Z coupling to ν_e with radiative return

Error on $g_Z^{\nu_e}$

Without detector resolution dilution effects

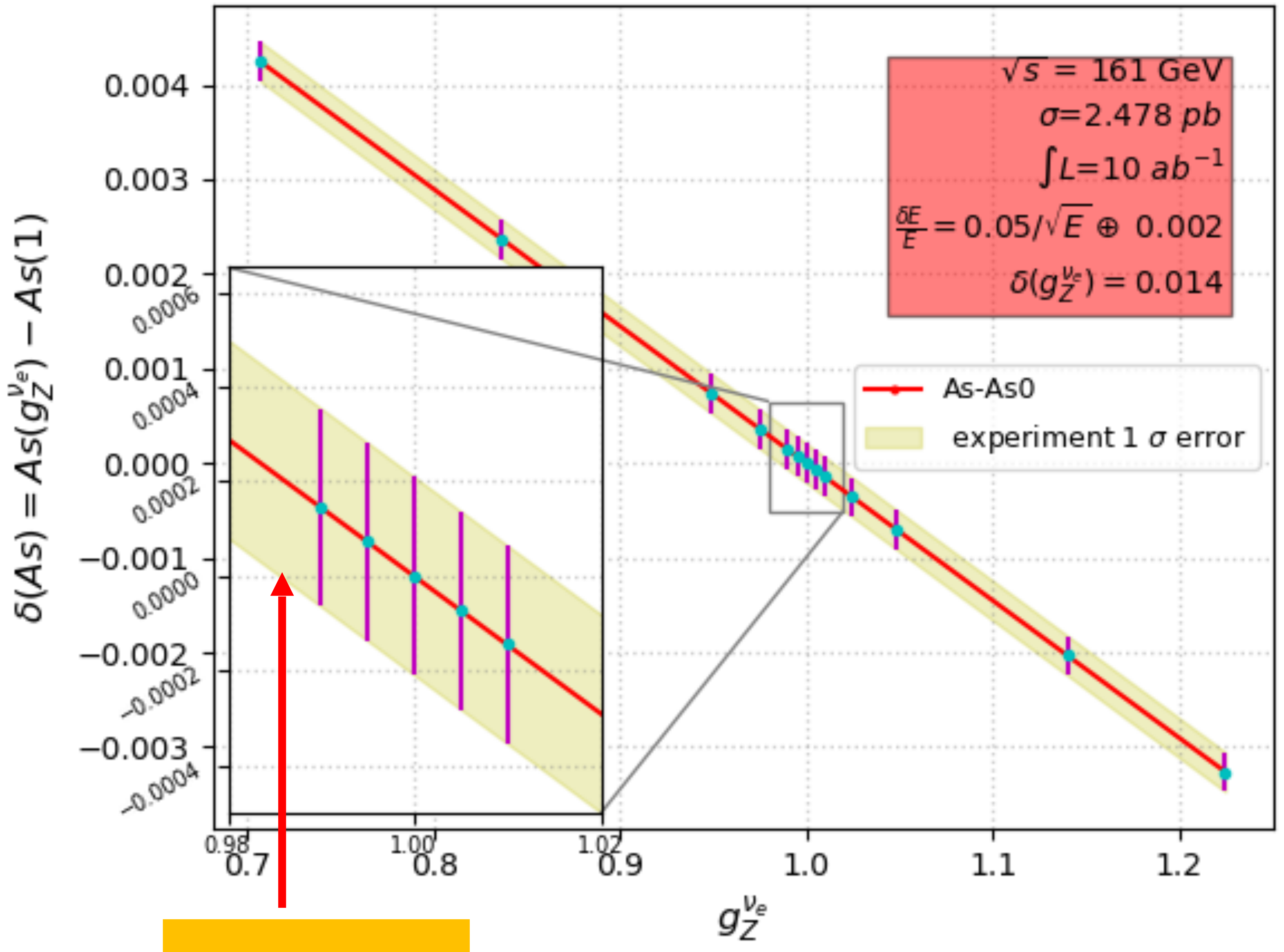


$\delta(g_Z^{\nu_e}) = \ \pm 0.95\%$

With detector resolution dilution effects

$$\frac{\delta E_\gamma}{E_\gamma} = \frac{0.05}{\sqrt{E_\gamma}} \oplus 0.005$$

Can be calibrated with μμγ events



$\delta(g_Z^{\nu_e}) = \ \pm 1.4\%$

If stochastic term =**3%** (Excel. Xtal detector) ⇨ $\delta(g_Z^{\nu_e}) = \ \pm 1.2\%$

If stochastic term =**7%** (sampling detector) ⇨ $\delta(g_Z^{\nu_e}) = \ \pm 1.8\%$

If stochastic term =**10%** (sampling detector) ⇨ $\delta(g_Z^{\nu_e}) = \ \pm 2.4\%$

→ Xtal-type calorimeter is highly desired!

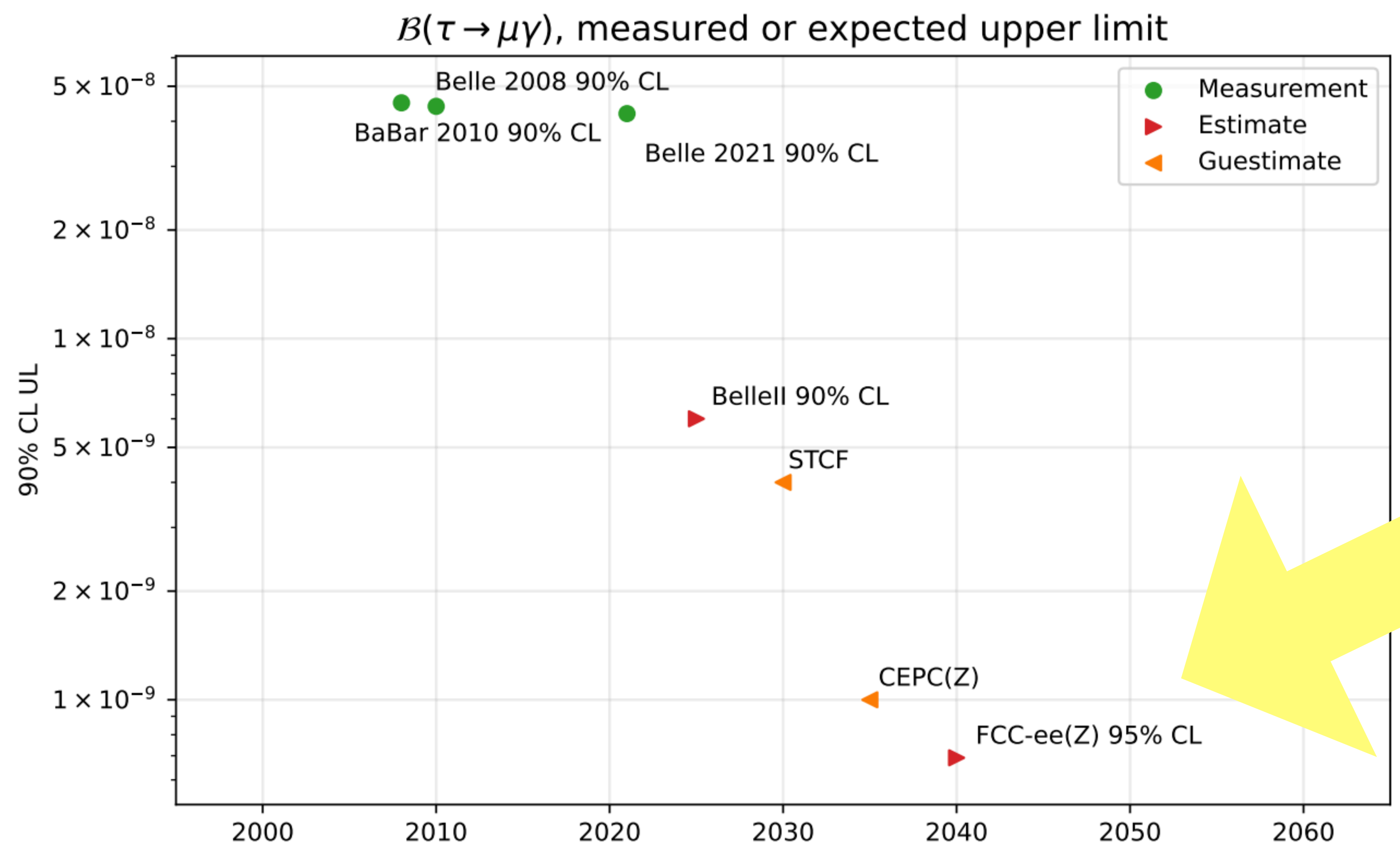
Caveat : Study of the optimal range of E_γ is to be done to optimize the sensitivity. However general conclusion for calorimeter is likely to be the same

R. Aleksan, S. Jadach https://arxiv.org/pdf/1908.06338.pdf

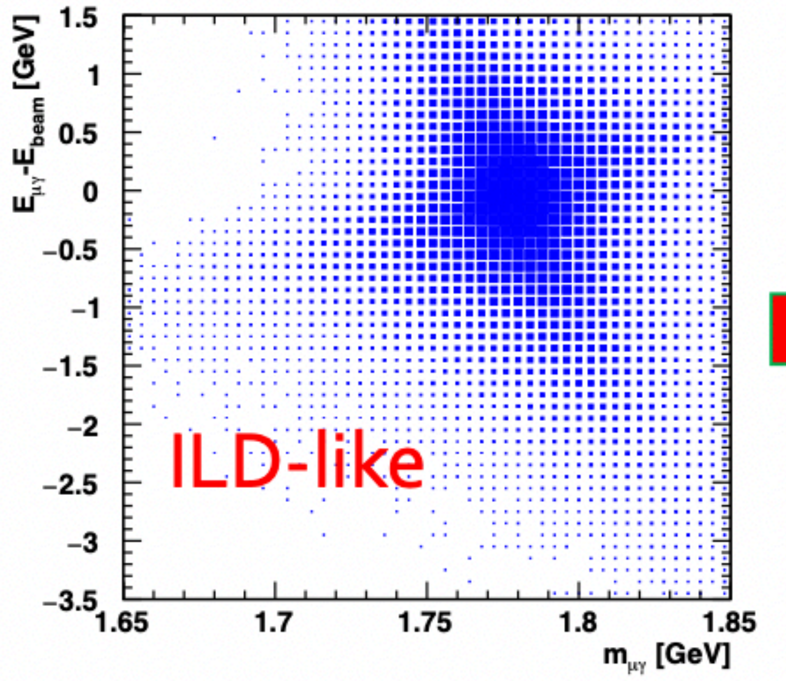
REQUIREMENTS FROM TAU PHYSICS: LFV $\tau \rightarrow \mu\gamma$

A. Lusiani - FCC Week 2023

- FCC-ee statistics ~8×10^{10} τ pairs comparable to Belle II
- $\tau \rightarrow \mu\gamma$ reach improves with:
  - Energy resolution of the EM calorimeter
  - Angular granularity of the EM calorimeter
  - Efficiency & purity of muon PID
- The background, flat in m, but rises linearly in energy. Limit improves with σ_E
  - Factor 4 improvement in going from 16.5%√E to 1.5% Babar-like

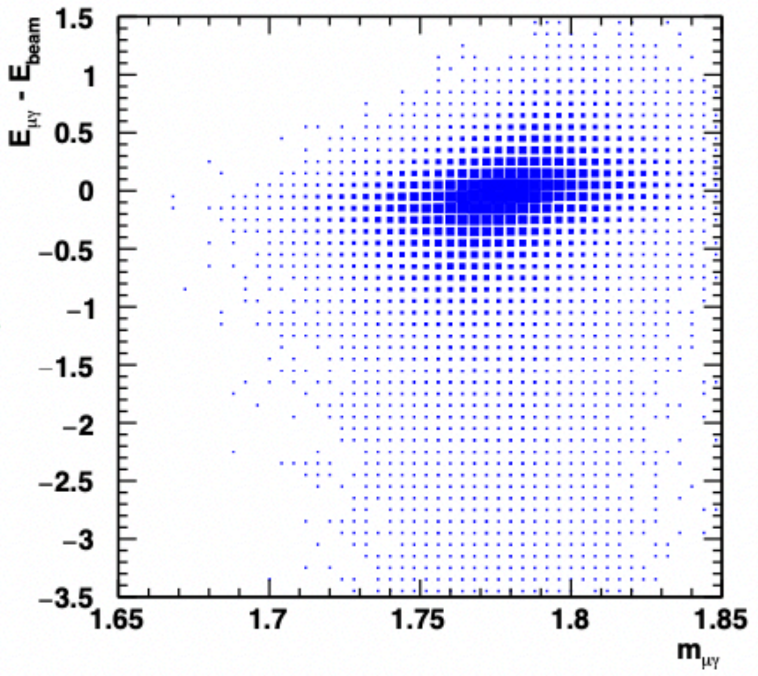


Play a game



Same ECAL **anglar** resolution

BaBar-like flat 1.5% ECAL **energy** resolution

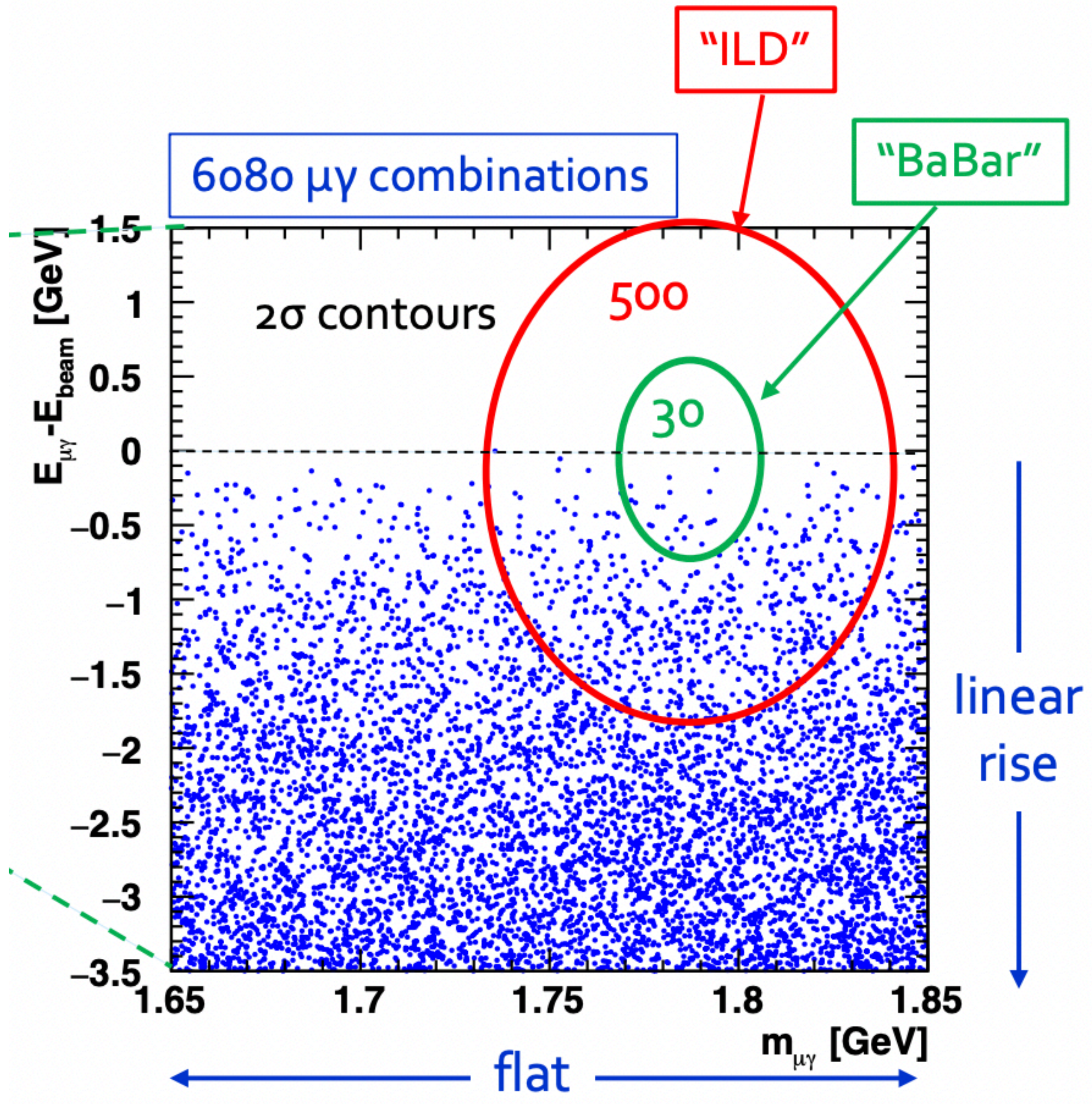


σ_m: 27 → 22 MeV

σ_E: 850 → 270 MeV

BR limit: 2.2×10^{-9}

M. Dam 1st FCC WS



of background